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Improvements in the Control of Ribes by Chemical and Mechanical Methods

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Agricultural Research Administration

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IMPROVEMENTS IN THE CONTROL OF RIBES BY CHEMICAL AND MECHANICAL METHODS[1,2]

By H. R. Offord, *pathologist*, V. D. Moss, *forest ecologist*, W. V. Benedict, *forester*, H. E. Swanson, *pathologist*, and A. London, *forester*, Region IV (Western), *Bureau of Entomology and Plant Quarantine, Agricultural Research Administration*

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INTRODUCTION

Chemical and mechanical methods of ribes eradication have played an important part in the control of white pine blister rust (*Cronar-*

[1] Received for publication April 28, 1952.

[2] Blister rust control investigations at Berkeley, Calif., are conducted by the Bureau of Entomology and Plant Quarantine in cooperation with the University of California, College of Agriculture, through the School of Forestry. Many phases of this work have been aided by cooperators in the University of California, the Forest Service, the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the University of Idaho.

The work described in this circular was done under the direction of J. F. Martin, in charge of the former Division of Plant Disease Control, Bureau of Entomology and Plant Quarantine. J. F. Breakey, C. R. Quick, and L. P. Winslow (resigned October 1947) made major contributions, and R. T. Bingham, W. S. Burrill, J. G. Gynn, F. O. Walters, C. P. Wessela, and operations personnel of the former northwestern and Pacific coast blister rust control regions assisted in greenhouse or field tests. The photographic work was done by H. M. Cowling. The special accessories for the tractor unit were designed and constructed in collaboration with the Forest Service, Region 5, Division of Engineering. Helicopter tests in 1949–50 in Idaho and Montana were made in cooperation with the Forest Service, Region 1, Division of Timber Management.

The American Chemical Paint Company, Ambler, Pa., and the Dow Chemical Company, Midland, Mich., provided test quantities of chlorinated phenoxy compounds.

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tium ribicola Fischer) throughout the Western States since 1924 (Martin *13*, Offord *18*, Offord *et al.*, *19*).[3] Since 1928, when sodium chlorate was first used extensively for killing *Ribes petiolare* Dougl. in northern Idaho, these methods have lowered costs of control and have offered feasible means of destroying ribes in pine areas where pulling or grubbing by hand tools was less effective and costly. The purpose of this circular is to summarize unpublished data from laboratory, greenhouse, and field work from 1937 through 1949 on methods development with particular reference to the recent improvements that have contributed most to the control program.

In Idaho, Montana, and Washington blister rust (pl. 1, *A*) is a menace on 3 million acres supporting western white pine (*Pinus monticola* Dougl.) (pl. 1, *B*) having a combined present and future stumpage value of 655 million dollars. In California and Oregon blister rust is a threat to sugar pine (*P. lambertiana* Dougl.) (pl. 1, *C*) and western white pine on 4,900,000 acres having a combined present and future stumpage value of 818 million dollars. Other species affected are northern white pine (*P. strobus* L.), limber pine (*P. flexilis* James), whitebark pine (*P. albicaulis* Engelm.), Mexican white pine (*P. ayacahuite* Engelm.), foxtail pine (*P. balfouriana* Murr.), and bristlecone pine (*P. aristata* Engelm.). There is no practical way to protect these valuable stands of white pine from blister rust damage except by eradicating nearby ribes, the alternate host plants (Klebahn *7*, Martin *12*, Mielke *15*, Spaulding *22*).

In the Western States about 25 species of wild ribes are found in sufficient numbers to be of importance to the blister rust control program. The disease is now present in or close to timber-producing and recreational areas of California, Oregon, Washington, Idaho, Montana, Wyoming, and Colorado (fig. 1). During the past 12 years the rust has become distributed at damaging potential throughout the valuable white pine stands of northern Idaho. It has not yet increased dangerously in the Sierra Nevada of California, but owing to the difficulty of suppressing *Ribes roezli* Regel. in many of the better pine sites much fine sugar pine land is left with only partial protection. These factors point up the need for cheaper, more effective, and especially more rapid methods of ribes control.

Hand pulling and grubbing are still the principal methods of killing ribes in white pine forests of the United States. Nevertheless, these hand methods have been tedious and costly where ribes bushes (1) occur in dense populations, (2) have developed multiple root systems that are difficult to locate and have trailing vines that break readily, (3) are unusually large and have extensive and deep roots, (4) are rooted under logs or stumps or in rock crevices, (5) have roots that are protected by and intertwined with those of other woody plants, and (6) are small and therefore difficult to identify in dense associated vegetation. These conditions have prevailed to a much greater extent in the Western States than elsewhere,[4] and it has been in this region that the greatest effort has been made to devise special methods of control.

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[3] Italic numbers in parentheses refer to Literature cited, p. 71.

[4] Under the supervision of project leaders H. N. Putnam, E. C. Filler, and J. C. Ball, tests have been undertaken in the North Central, Northeastern, and Southern Appalachian white pine regions, where limited field use has been made of herbicides and special tools.

A, Stem canker on western white pine. Arrows show probable point of initial infection and typical constriction of stem at center of fruiting trunk canker. *B*, Stand of young mature western white pine, St. Joe National Forest, Idaho. *C*, Typical group of mature sugar pine, Sierra National Forest, Calif.

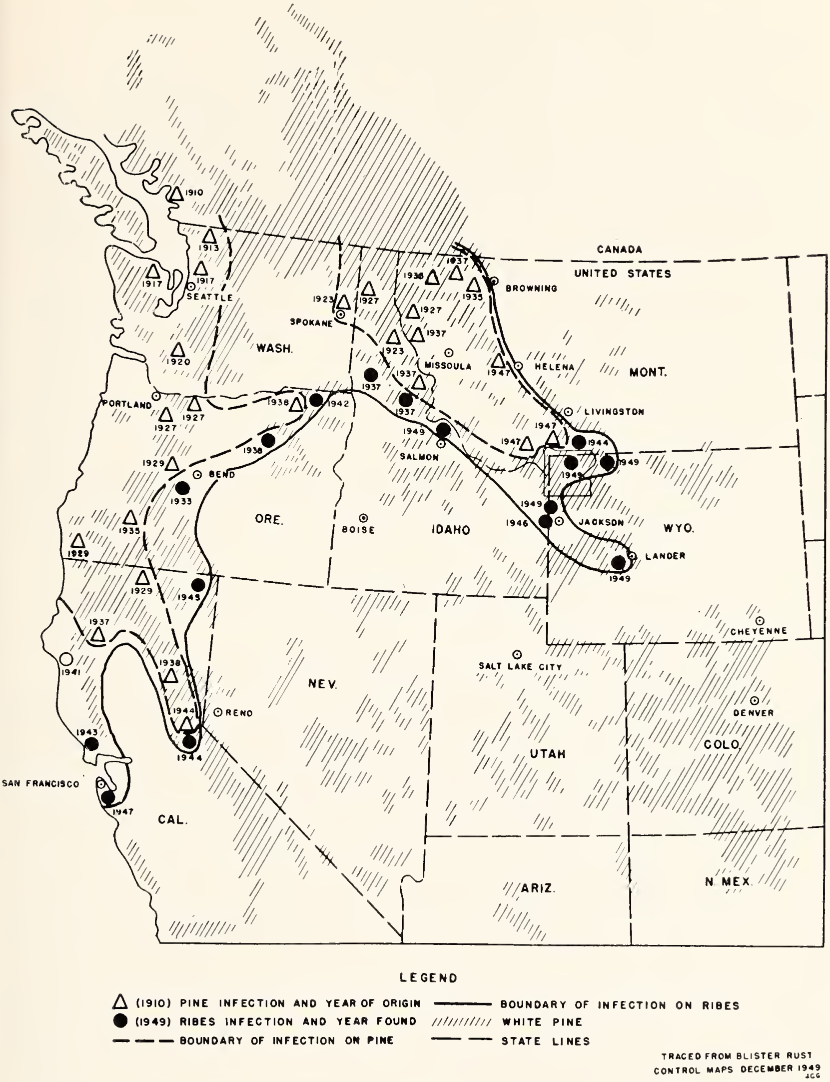

FIGURE 1.—Distribution of white pine and spread of blister rust on pine and ribes in the Western States, 1910–49.

Each *Ribes* species has constituted a separate problem in the development of chemicals and equipment for field use. Spraying has proved to be the only feasible means of removing the important *petiolare* from white pine forests in northern Idaho. Decapitation and chemical treatments of the cut-off crowns of ribes bushes that are troublesome to dig or pull have been successful in all white pine regions. In practical control work the scope of spraying, decapitation, and more recently basal-stem treatment has been greatly expanded by the use of the chlorinated phenoxy weed killers 2,4-di-

chlorophenoxyacetic and 2,4,5-trichlorophenoxyacetic acids and their derivatives, commonly known as 2,4-D or 2,4,5-T.

The results of investigations through 1936 on chemical and mechanical methods of ribes eradication in the Western States were summarized by Offord *et al.* (*19*). From 1937 through 1949 encouraging progress was made in the adaptation and use of new herbicides, in the improvement of equipment for applying these herbicides, and in the design of efficient tools for the mechanical eradication of ribes. Since 1946 the use of sulfamates, Diesel oil, salt-borax mixtures, dynamite, and special power tools has largely been superseded by chemical methods employing 2,4-D and 2,4,5-T.

Complete reports on ribes-ecology studies in relation to white pine management (Davis and Moss *4*, Dunning *5*, Quick[5]) and economics of blister-rust control (Martin *11*, Matthews and Hutchison *14*, Vaux *23*) are available. The application of these findings to field procedures and the proficiency in control operations resulting from the use of a contract system and one-man crews are important improvements in methods of ribes eradication. The new herbicides and the methods for applying them and the improved equipment described in this circular all relate to and are fully usable in forest-management work or in that done by contractors and one-man crews.

CHEMICAL METHODS OF RIBES ERADICATION

Scope of Recent Methods-Development Work

In the development of chemical methods from 1937 through 1949 several thousand greenhouse and field tests were made in which the chemicals were applied as sprays, aerosols, and dusts to intact and decapitated plants. Procedures for the testing of herbicides included preliminary screening in the greenhouse at Berkeley, Calif., followed by small-scale field trials of the more promising chemicals and later by large-scale tests (Offord *et al.*, *19*).

These herbicides have been applied as foliage sprays, combination foliage sprays and soil drenches, soil drenches alone, as basal-stem treatments of intact and scarified plants, and as treatments of the freshly cut-off stems or root crowns. Spreaders, stickers, markers, hygroscopic agents, and activators have been combined with the herbicides used in field tests. For the important herbicides the effects of soil type, seasonal development of the ribes, age of plants, varietal forms of *Ribes*, and method of treatment were studied in relation to the concentration and dosage needed for satisfactory kill (85 percent or more of treated bushes). Hazards of applying the herbicide were considered with respect to safety and health of the operator, fire hazard to the woods, toxicity to animals, and maintenance of equipment.

During the first few years of this study about equal consideration was given to herbicides and to hand tools and power equipment for mechanical eradication of ribes. Diesel oil, sodium chlorate, and ammonium sulfamate were used in the field as combined foliage sprays

[5] Clarence R. Quick, Ecology and Control of the Sierra Nevada Gooseberry, 35 pp. unpublished report, September 24, 1951.

and soil drenches and to some extent for the treatment of cut-off root crowns. A dry mixture of salt and borax was the principal herbicide used for treating the root crown of decapitated plants.

Since the first successful test of 2,4–D on *roezli* in December 1944, methods-development work has been devoted largely to testing the chlorinated phenoxy herbicides, and to the adaptation of equipment for applying them in the field. In greenhouse tests about 500 formulations of chlorinated phenoxy and related organic compounds were applied as sprays, dusts, and aerosols to intact and decapitated plants.

From 1945 through 1949, 1,758 field plots were established in Idaho, Oregon, and California primarily for testing 2,4-D and 2,4,5-T. About 43,000 ribes plants were included in these tests. More than half of the tests have been concerned with *roezli*, the species that represents about 90 percent of the control job in sugar pine areas of California.

Methods of Applying Herbicides

Four methods of application have been used in the testing of chemicals on ribes. They are as follows:

(1) Spraying or dusting the foliage and stems of intact plants with a large or small volume of the liquid chemical. In all testing work, spraying has meant thorough coverage of the above-ground parts of the plants with a specified concentration of chemical applied uniformly so that each plant receives about the same dosage. When the specified dosage exceeds the quantity needed to cover the foliage and stems, it is sprayed uniformly over the ground within plot boundaries. Dusting may be regarded as a dry spray insofar as the method of application is concerned.

(2) Treating the root crown or the short ends of stems of freshly cut-off plants. The liquid concentrate of the herbicide or the dry powder is applied directly to freshly exposed cambial tissue of the root crown or to the ends of all the stems that have been cut off as close as possible to the root crown.

(3) Wetting the basal portions of intact or scarified stems of erect or semierect bushes with small volumes of a translocatable herbicide, such as 2,4-D or 2,4,5-T in an oil diluent.

(4) Drenching the soil around the root centers of the plants. The herbicide is applied only to the soil in a coarse spray or as a solid stream, no attempt being made to treat stems or leaves. The effectiveness of this treatment depends upon absorption of the chemical by the roots or upon a contact killing of all living root and crown tissue.

Spraying the foliage and stems of intact plants has been the most generally useful method for evaluating herbicides in blister rust control work. Spraying provides the most critical test of a herbicide for the control of a deep-rooted vigorous woody perennial. Any terrestrial plant can be killed if enough of the chemical is applied to the soil, but few chemicals have killed woody perennials when applied only to the stems and leaves. Herbicides such as the chlorates, oils, and thiocyanates showed considerable variation in their effect on ribes, but no one of them was fully effective unless some of the chemical was applied to the soil in the course of spraying the tops. Drenching the soil to kill the roots directly requires large quantities of both diluent and herbicide. For chemical control of a deep-rooted woody

perennial, such as ribes, that does not usually have its absorbing roots near the soil surface, soil treatment by itself has not been so effective as spraying or decapitation. Of the translocatable growth-regulating substances, 2,4-D and 2,4,5-T have been outstanding in producing a profound systemic effect in a ribes plant from small dosages applied to leaves and stems.

Although results with 2,4-D dusts have been more erratic than those with sprays, 2,4-D has been the only herbicide that has killed ribes when applied as a dust. *Ribes roezli*, *nevadense* Kell., and *petiolare* have been killed by a 5-percent dust of the 2,4-D ester when applied to the stems and leaves of the intact plants.

Preliminary Tests

Greenhouse and field tests were made to evaluate the herbicides against the principal species of *Ribes* occurring in the white pine areas of California, Colorado, Idaho, Montana, Oregon, Washington, and Wyoming, and against three species—*glutinosum* Benth, *menziesi* Pursh., and *speciosum* Pursh.—in greenhouse tests at Berkeley. Five other species, not listed, from the North Central, Northeastern, and Southern Appalachian regions were grown from seed at Berkeley and were included in a few tests to extend data on the sensitivity of the recognized taxonomic groups of ribes to 2,4-D and 2,4,5-T.

A total of 130 chemicals and chemical mixtures were tested. Some of them were made in the blister rust laboratory at Berkeley, some were obtained from the manufacturers, and some were supplied by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine. The chemicals used and the *Ribes* species against which they were tested are given below. Solvents or wetting agents are not shown unless they were added to increase the effectiveness of the principal chemical.

CHLORINATED PHENOXY COMPOUNDS TESTED AS HERBICIDES ON RIBES, 1944–49

2,4-D COMPOUNDS*

Chemical [1]	Species of *Ribes*
Acid [2]	*binominatum, bracteosum, cereum, inerme, lacustre, lobbi, nevadense, petiolare, roezli, viscosissimum*
Acid plus—	
furfural	*binominatum, bracteosum, cereum, glutinosum, inerme, lacustre, lobbi, nevadense, petiolare, roezli, sanguineum, viscosissimum*
phenylacetic acid plus glycerol	*lacustre, nevadense, viscosissimum*
polyethylene glycol [2 3]	*cereum, lacustre, nevadense, roezli, viscosissimum*
polyethylene glycol plus ammonium sulfamate.[2]	*menziesi, roezli*
tributyl phosphate plus kerosene [3 4]	*binominatum, viscosissimum*
Alkanolamine salt. [2 3 4]	*binominatum, cereum, cruentum, erythrocarpum, klamathense, lacustre, lobbi, marshalli, nevadense, roezli, sanguineum, viscosissimum*
Alkanolamine salt plus ammonium sulfamate.[2]	*binominatum, lobbi, roezli, viscosissimum*
Ammonium salt [2]	*cereum, lacustre, lobbi, nevadense, roezli, sanguineum, viscosissimum*

See footnotes at end of table.

CHLORINATED PHENOXY COMPOUNDS TESTED AS HERBICIDES ON RIBES, 1944-49—Continued

2,4-D COMPOUNDS*—continued

Chemical [1]	Species of *Ribes*
Ammonium salt plus—	
ammonium trichloroacetate	*binominatum, erythrocarpum*
ammonium dihydrogen phosphate plus potassium chloride plus glycerol	*binominatum, cereum, lacustre, nevadense, petiolare, roezli, viscosissimum*
ammonium salt, ortho-chlorophenoxyacetic acid	*binominatum, bracteosum, cereum, inerme, lacustre, lobbi, nevadense, petiolare, roezli, sanguineum, viscosissimum*
glycerol	*klamathense, lacustre, nevadense, roezli, viscosissimum*
Butyl ester [2 3 4]	*binominatum, bracteosum, cereum, erythrocarpum, glutinosum, inerme, klamathense, lacustre, lobbi, marshalli, nevadense, petiolare, roezli, sanguineum, viscosissimum*
Butyl ester plus—	
Diesel oil [3 4]	*nevadense*
kerosene [3 4]	*cereum, lobbi, nevadense, roezli, sanguineum*
summer oil emulsion [2]	*lacustre, nevadense, roezli, viscosissimum*
triethylene glycol plus mono- and diethyl-phosphoricacids (mixed)	*lacustre, viscosissimum*
Ethyl ester [3 4]	*binominatum, bracteosum, cereum, inerme, lacustre, nevadense, petiolare, sanguineum, viscosissimum*
Isopropyl ester [3 4]	*binominatum, bracteosum, cereum, inerme, lacustre, nevadense, petiolare, roezli, sanguineum, viscosissimum*
Isopropyl ester plus—	
Diesel oil [3 4]	*nevadense, roezli, viscosissimum*
kerosene [3 4]	*binominatum, cereum, glutinosum, menziesi, lacustre, lobbi, nevadense, roezli, sanguineum, viscosissimum*
weed-killer oil (aromatic) [3 4]	*cereum, nevadense, roezli*
Methyl ester [3]	*binominatum, cereum, erythrocarpum, lacustre, lobbi, nevadense, roezli, viscosissimum*
Methyl ester plus—	
ammonium beta-naphthoxyacetate	*lobbi, roezli, sanguineum*
ammonium sulfamate [2]	*nevadense, roezli*
fuel oil [3]	*lacustre, viscosissimum*
kerosene [3 4]	*binominatum, lacustre, petiolare, viscosissimum*
potato extract (aqueous)	*lacustre, viscosissimum*
Sodium salt 2-methyl-4-chlorophenoxyacetic acid	*cereum, cruentum, inerme, lacustre, lasianthum, petiolare, nevadense, roezli, sanguineum, viscosissimum*
Sodium salt [3 4]	*binominatum, bracteosum, cereum, cruentum, erythrocarpum, glutinosum, inerme, lacustre, laxiflorum, lobbi, marshalli, menziesi, montigenum, nevadense, petiolare, roezli, sanguineum, speciosum, triste, tularense, viscosissimum*
Sodium salt plus—	
ammonium sulfamate [2]	*roezli*
ferric oxalate	*cereum, lacustre, nevadense, roezli, viscosissimum*
furfural	*nevadense, roezli, tularense*

See footnotes at end of table.

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CHLORINATED PHENOXY COMPOUNDS TESTED AS HERBICIDES ON RIBES, 1944–49—Continued

2,4-D COMPOUNDS*—continued

Chemical [1]	Species of *Ribes*
Sodium salt plus—Continued	
glutathione	*lacustre, sanguineum*
glycerol	*nevadense, roezli*
onion extract, aqueous	*lacustre, petiolare, viscosissimum*
para-aminobenzoic acid	*cereum, lacustre, roezli*
propylene glycol	*nevadense, roezli*
quinone	*lacustre, roezli, setosum*
sodium beta- naphthoxyacetate	*lobbi, sanguineum*
sodium chlorate	*nevadense, roezli*
summer oil emulsion (light-medium)	*cereum, nevadense, roezli*
toluidine blue O	*lacustre, nevadense, roezli*
triethylene glycol	*nevadense, roezli*
xanthogen disulfide	*lacustre, roezli, viscosissimum*

2,4,5-T COMPOUNDS*

Chemical [1]	Species of *Ribes*
Acid	*lacustre, petiolare, viscosissimum*
Acid plus—	
Tributyl phosphate plus kerosene [4]	*binominatum, cereum, erythrocarpum, lacustre, lasianthum, lobbi, petiolare, roezli, viscosissimum*
Sodium salt	*cereum, lacustre, lobbi, petiolare, viscosissimum*
Sodium salt plus sodium pentachlorophenate	*binominatum*
Butyl ester [3]	*tularense*
Ethyl ester plus—	
fuel oil	*lacustre, viscosissimum*
kerosene [3 4]	*binominatum, cereum, inerme, lacustre, lobbi, montigenum, petiolare, sanguineum, viscosissimum*
stove oil	*lacustre*
Isopropyl ester [3 4]	*lacustre, viscosissimum*
Isopropyl ester plus—	
Diesel oil [3 4]	*cereum, lacustre, montigenum, viscosissimum*
Geon latex 31–X	*lacustre, viscosissimum*
kerosene [3 4]	*lacustre, montigenum, viscosissimum*
mono and diethylphosphoric acid (mixed)	*nevadense, roezli*
soluble oil (dormant, emulsive)	*acerifolium, lacustre, laxiflorum, montigenum, setosum, viscosissimum, watsonianum*
stove oil	*lacustre, viscosissimum*
summer oil emulsion	Do.
weed-killer oil (Shell No. 20) [4]	*cereum, lasianthum, montigenum, nevadense, roezli*
Triethanolamine salt	*binominatum, erythrocarpum, lacustre, lobbi, petiolare, sanguineum, viscosissimum*
Triethanolamine salt plus ammonium sulfamate	*binominatum, lobbi, viscosissimum*
Isopropyl and amyl esters (mixed)	*nevadense, roezli*
Isopropyl and amyl esters (mixed) plus—	
Diesel oil [3 4]	*nevadense, roezli*
kerosene	Do.
soluble oil (dormant, emulsive)	*cereum, inerme, montigenum, setosum*
summer oil emulsion	*nevadense, roezli*
weed-killer oil (aromatic) [3 4]	*cereum, inerme, nevadense, roezli*
xanthogen disulfide	*nevadense, roezli*

See footnotes at end of table.

CHLORINATED PHENOXY COMPOUNDS TESTED AS HERBICIDES ON RIBES, 1944–49—Continued

MIXTURES OF 2,4-D AND 2,4,5-T COMPOUNDS*

Chemical [1]	Species of *Ribes*
Isopropyl ester of 2.4-D plus isopropyl and amyl esters (mixed) of 2,4,5-T plus—	
Diesel oil [4]	*nevadense, roezli*
glycerol	Do.
mono and diethylphosphoric acid (mixed)	Do.
summer oil emulsion	Do.
weed-killer oil (aromatic) [4]	Do.
Butoxyethanol ester of 2,4-D plus butoxyethanol ester of 2,4,5-T [4]	*cereum, lacustre, montigenum, nevadense, roezli, tularense, viscosissimum*
Sodium salt of 2,4-D plus isopropyl and amyl esters (mixed) of 2,4,5-T plus summer oil	*roezli*

MISCELLANEOUS COMPOUNDS TESTED AS HERBICIDES ON RIBES, 1937–49

Chemical [1]	Species of *Ribes*
Adrenaline chloride	*glutinosum, roezli*
Ammonium hexachlorophenate [2]	*binominatum, cereum, inerme, lacustre, lobbi, nevadense, petiolare, roezli, viscosissimum*
Ammonium sulfamate* [2 3]	*binominatum, bracteosum, cereum, coloradense, cruentum, erythrocarpum, inerme, irriguum, klamathense, lacustre, lobbi, montigenum, nevadense, petiolare, roezli, sanguineum, triste, tularense, viscosissimum*
Ammonium sulfamate plus—	
alpha-naphthaleneacetic acid**	*roezli*
furfural*	Do.
indole-3-propionic acid**	Do.
Ammonium trichloroacetate*	*binominatum*
3-Amino-4-methoxyacetophenone plus morpholine	*lacustre, viscosissimum*
Benzene phosphonic acid	*lacustre, roezli*
Benzidine sulfamate** [2]	*roezli*
Benzophenone [2]	*binominatum, cereum, cruentum, inerme, lacustre, lobbi, nevadense, petiolare, roezli, sanguineum, viscosissimum*
Bis(*p*-chlorophenyl) acetic acid**	*lacustre, roezli*
Borophosphoric acid	Do.
Carbamide phosphoric acid	Do.
Copper sulfamate** [2]	*roezli*
Diesel oil* [2 3 4]	*binominatum, cereum, inerme, irriguum, lacustre, montigenum, nevadense, roezli, tularense, viscosissimum*
Diesel oil plus—	
allyl (mixed) chlorophenyl carbonate*	*binominatum, erythrocarpum, lobbi*
crankcase oil* [2 3]	*cereum, inerme, montigenum*
crude oil* [2]	*nevadense, roezli*
furfural* [2 3 4]	*cereum, inerme, lacustre, montigenum, nevadense, roezli*
furfural plus ammonium thiocyanate* [2 3 4]	Do.
sulfur dioxide extract from lubricating oil* [2]	*nevadense, roezli*

See footnotes at end of table.

MISCELLANEOUS COMPOUNDS TESTED AS HERBICIDES ON RIBES, 1937–49—Continued

Chemical [1]	Species of *Ribes*
Diethyl acid orthophosphate	*lacustre, roezli*
Diphenyl sulfamate** [2]	*roezli*
Ethylenediamine plus pentanedione-2,4.** [2]	*glutinosum, roezli*
Ethylenediamine plus pentanedione-2,4 plus copper sulfate.** [2]	Do.
Glutathione	*lacustre, petiolare, viscosissimum*
Hexabutyl tetraphosphate	*lacustre, roezli*
Hexapropyl tetraphosphate	Do.
4-Methoxy-3-nitroacetophenone plus morpholine	*lacustre, viscosissimum*
Methyl dichloroacetate	*lacustre, roezli*
Monobutyl acid orthophosphate	Do.
Monoethyl acid orthophosphate	Do.
o-(Phenylenedioxy) diacetic acid	Do.
o-(Phenylenedioxy) diacetic acid, dimethyl ester	Do.
Phenazine plus ethyl alcohol	*menziesi, roezli*
Phenazine oxide plus triethanolamine	*lacustre, roezli*
Phenylphosphinic acid	Do.
Phenyl ester of 3,4-dichlorobenzenesulfonic acid**	*binominatum, lacustre, viscosissimum*
Sodium chlorate plus sodium pentachlorophenate*	*roezli*
Sodium chloride plus borax* [3]	*cereum, cruentum, irriguum, lacustre, montigenum, nevadense, roezli, viscosissimum*
Sodium chlorosulfonate** [2]	*petiolare, roezli*
Sodium ethyl xanthate* [2] [3]	*cereum, inerme, nevadense, petiolare*
Sodium thiocyanate* [2] [3]	*bracteosum, cereum, nevadense, roezli, viscosissimum.*
Sodium trichloroacetate*	*binominatum*
Tetrabutyl pyrophosphate	*lacustre, roezli*
Tetraethyl pyrophosphate	Do.
Tetramethyl pyrophosphate	Do.
Tetrapropyl pyrophosphate	Do.
Trioxane* [2]	*glutinosum, roezli*
Xanthogen disulfide**	*lacustre, roezli, viscosissimum*

[1] All chemicals applied as sprays to foliage unless otherwise indicated.
[2] Applied to soil.
[3] Applied to root crown.
[4] Applied to basal stem.

Many of these chemicals killed so few of the ribes plants in the greenhouse or in a single group of field tests, that they were not tested further. Others were not available in sufficient quantity for field tests, or were hazardous, costly, or inconvenient to use in the field for ribes eradication. The chemicals that killed more than 50 percent of the treated plants and have shown some merit for extensive use in ribes eradication work are marked with an asterisk; this class includes all the chlorinated phenoxy compounds, all the oils, ammonium sulfamate, ammonium sulfamate in furfural, ammonium trichloroacetate, sodium chlorate mixed with pentachlorophenate, sodium chloride mixed with borax, sodium ethyl xanthate, sodium thiocyanate, and sodium trichloroacetate. Chemicals that killed more than 50 per-

cent of test ribes but are not now practical for field use are marked with two asterisks. The remaining chemicals were not sufficiently effective to pass greenhouse screening test.

Field Tests With Effective Chemicals

SPRAY TREATMENT

AMMONIUM SULFAMATE

Although the toxicity of sulfamates to plants was noted as early as 1896 (Loew *9*), it was not until 1942 that ammonium sulfamate was manufactured and made available in this country for weed-killing purposes. From 1942 through 1945 this compound and Ammate, a proprietary weed killer containing ammonium sulfamate, were tested in the field on *binominatum*, *bracteosum*, *cruentum*, *erythrocarpum*, *inerme*, *lacustre*, *montigenum*, *nevadense*, *petiolare*, *roezli*, *sanguineum*, *tularense*, and *viscosissimum*. Aqueous solutions of this herbicide were applied as a spray, as a soil drench, and as a treatment for cut-off crowns. The dry material was also applied to cut-off crowns.

The price per pound of ammonium sulfamate in 1943 was about 16 cents compared with sodium chlorate at 8 cents, but the sulfamate killed a number of *Ribes* species with dosages less than half those needed for the chlorates. Furthermore, there is no fire hazard in the use of sulfamates as there is for the chlorates. However, ammonium sulfamate has a corrosive action on metal equipment and on leather, and is highly toxic to conifers.

Tests with sprays containing controlled dosages of ammonium sulfamate were made on nine species of *Ribes* that were not easily killed with other herbicides available at that time. Results of these tests on milacre (1/1000 of an acre) plots are shown in table 1. All plots treated at the same time and which subsequently showed 100 percent kill (or kills not differing by more than 5 percent) are shown in the table as a single-entry average for percent of bushes killed.

Ribes lacustre and *erythrocarpum* were killed with smaller dosages than were needed for other species. However, ammonium sulfamate was effective on all the *Ribes* species, the major limiting factors being the dosage, the character of the soil, and the depth and manner of distribution of ribes roots. Best results from the spraying on intact ribes were obtained with treatments made about the middle of the growing season when soils were moist and not too hot. All leaves and stems were thoroughly wet to the ground line, and the soil about the root center was drenched.

The sulfamates are highly soluble in water, 5 to 6 pounds per gallon being completely soluble. Aqueous solutions containing 3 pounds or more per gallon are useful for temporarily sterilizing soil or for treating cutoff root crowns. Sulfamates do not consistently show strong seasonal effects on ribes, but because of their high solubility they should not be applied just before or during an extended wet period.

TABLE 1.—*Effectiveness of ammonium sulfamate sprays on* Ribes *in California, Idaho, and Oregon, 1942–45*

Location and date applied	Dosage per milacre	*Ribes* species treated	Bushes treated	Bushes killed
	Pounds		*Number*	*Percent*
California:				
July 15, 1944	2	*bracteosum*	15	80
	4, 6, 8		51	100
July 19, 1944	2, 4	*inerme*	26	92
	6, 8		20	100
Aug. 6, 1943	4	*nevadense*	7	100
July 9, 1942	3, 5	*roezli*	25	92
	7, 10		21	100
Sept. 8, 1942	3, 5		28	93
	7, 10		24	100
Aug. 6, 1943	2		8	75
	4, 6, 10		35	100
July 21, 1944	4		81	89
Aug. 1, 1945	0.67	*tularense*	20	80
	1.34		25	90
	2		25	100
Idaho:				
Sept. 8, 1943	1, 2, 3, 5, 6, 8	*lacustre*	89	100
	0.8, 1.6, 2.4, 3.2, 4.8		43	100
June 10, 1944	0.4		15	93
	0.8, 1.6, 2.4, 4.8		43	100
July 18, 1944	3.2		8	75
Sept. 5, 1944	0.8, 1.6, 2.4, 3.2, 4.8		53	98
June 14, 1944	0.4	*viscosissimum*	32	82
	0.8		43	98
	1.6		37	97
	3.2		29	100
Sept. 9, 1944	2.4		14	64
	3.2		26	77
	4.8		18	100
Oregon:				
July 17, 1945	0.8	*binominatum*	33	88
	0.4, 0.8, 1.6	*erythrocarpum*	137	99
July 19, 1945	0.8, 1.6, 2.4	*lacustre*	14	100

DIESEL OIL

Oils have been employed in weed control for many years, and their properties and special uses are already a matter of record (Crafts and Reiber *3*). Diesel oil was tested early in experimental ribes eradication (Offord *et al.*, *19*), but it was not used in control work until 1938 in California. Two field problems generated new interest in oils—the heavy regeneration of *Ribes roezli* from seed in some of the high-quality sugar pine sites and an increase in the number of rock-bound ribes crowns encountered by eradication crews. Rocky terrain is common in the upper ranges of sugar pine and in many of the areas being worked by the National Park Service to protect whitebark pine, limber pine, and bristlecone pine.

Spraying young *roezli* bushes with oil was expected to minimize subsequent regeneration from soil-stored seed, partly through direct chemical action on the seed and partly by eliminating the soil disturbance of grubbing. Greenhouse tests had shown that low dosages

of Diesel oil (5,000 p. p. m. in air-dried soil) prevented germination of most of the seed planted in mountain soil. Other tests had shown that the type, temperature, and moisture of the soil all had important bearing on the effectiveness of Diesel oil to soil-stored ribes seed. The efficiency of Diesel oil as a plant killer depends upon the dosage, the toxicity of the oil itself, and upon its contact with the plant tissue. Laboratory studies on several soils taken from white pine forests of Idaho and California showed that the greatest retention and the most rapid and extensive movement of Diesel oil occurred in warm, lightly compacted, sandy silt loam soils having a moisture content between 10 and 20 percent. Many of these conditions prevail in upland areas of the Sierra Nevada in California during the long dry summer.

It is possible to increase the effectiveness of oils by adding oil-soluble or oil-miscible chemicals. Before the development of 2,4-D and related chemicals, one of the most satisfactory oil formulations for ribes control called for a combination of Diesel oil and furfural saturated with ammonium thiocyanate (Offord *16*). Such fortified oils are often economical to use for foliage sprays, basal-stem treatments, and on decapitated root crowns. For soil treatments, however, low-cost oils are usually cheaper than special oil formulations even though it may be necessary to employ them in larger quantities.

In certain favorable sites *roezli* has shown persistent and heavy regeneration from soil-stored seed when the eradication was done by grubbing. In 1938 a field study was begun to determine the practical lethal dosage of several oils on young *roezli* plants and also to compare their effectiveness against soil-stored seed. The plots were located on Chowchilla Mountain, Sierra National Forest, Calif. A barbed-wire fence protected the test area from trampling and grazing of cattle. Individual plot locations within the fenced area were assigned at random.

The oils selected for these tests were Diesel oil, crude oil (California, Kettleman field), and a waste refinery oil resulting from the sulfur dioxide extraction of lubricating oil. These oils were tested singly or in mixture at various dosages. Each dosage was applied uniformly so as to spray and drench each young ribes plant and simultaneously to treat the soil. The plots were sprayed on August 11 and 12, 1938, and examined for kill of bushes in July 1939. On the untreated check plots all bushes were carefully eradicated in 1938 by the regular hand-pulling and grubbing method. Beginning in 1939 and each year thereafter through 1947 all new seedlings were counted and then removed from all test plots.

The results of this 10-year study, given in table 2, show that the sulfur dioxide extract alone or mixed with Diesel oil is somewhat more effective as an herbicide than Diesel oil with or without crude oil. This conclusion is based on the bush kill from dosages of 1 to 2 gallons per milacre and on their effectiveness on soil-stored seed as expressed indirectly by the number of seedlings that appeared on the plots between 1939 and 1947. Seedlings were removed each season until 1947, when five were found on only one untreated plot. For all the oils tested a dosage of 3 gallons or more per milacre gave practically complete bush kill and destroyed or prevented germination of all but an occasional *roezli* seed.

In operations work herbicides are applied selectively to ribes bushes unless they occupy all available ground or a special objective necessitates broadcast coverage. To obtain more information on dosage a second series of oil tests was made on *roezli* during 1938 on $\frac{1}{40}$-acre and unmeasured plots on Chowchilla Mountain. Light, medium, and heavy dosages (fig. 2, legend) were used. Diesel oil and sulfur dioxide extract alone were compared with several mixtures of the two. One test was made of a 1:1 mixture of Diesel oil and crude oil. The dosages and results of these tests are summarized in table 3. For the $\frac{1}{40}$-acre plots the effectiveness of the three dosages of these oils is shown graphically in figure 2.

TABLE 2.—*Effectiveness of various dosages of oils on* Ribes roezli *seedlings, Chowchilla Mountain, Sierra National Forest, Calif. Plots sprayed on Aug. 11 and 12, 1938. Summary of data 1938–47*

Oil and gallons per milacre	Bushes treated	Bushes killed	Current-season seedlings removed from plots	
			1939	Total 1939–47
	Number	*Percent*	*Number*	*Number*
Sulfur dioxide extract:				
1	43	93	0	0
1.5	105	96	2	6
2	55	100	0	0
3	70	100	0	0
5	137	99	0	0
10	94	100	0	0
Diesel:				
1	18	83	1	2
1.5	85	96	8	10
2	76	93	4	9
3	56	100	0	0
5	59	100	0	0
10	35	100	0	0
Diesel plus crude (1:1):				
1	58	71	54	113
1.5	94	91	17	30
2	21	81	9	25
3	109	100	1	1
5	110	95	1	9
10	65	100	0	0
Sulfur dioxide extract plus Diesel (1:1):				
1	77	92	93	147
1.5	210	94	22	37
2	23	96	7	45
3	46	100	3	9
5	127	100	0	5
10	135	100	0	0
Untreated check:				
0	209	0	87	155
	25	0	137	240
	170	0	81	151

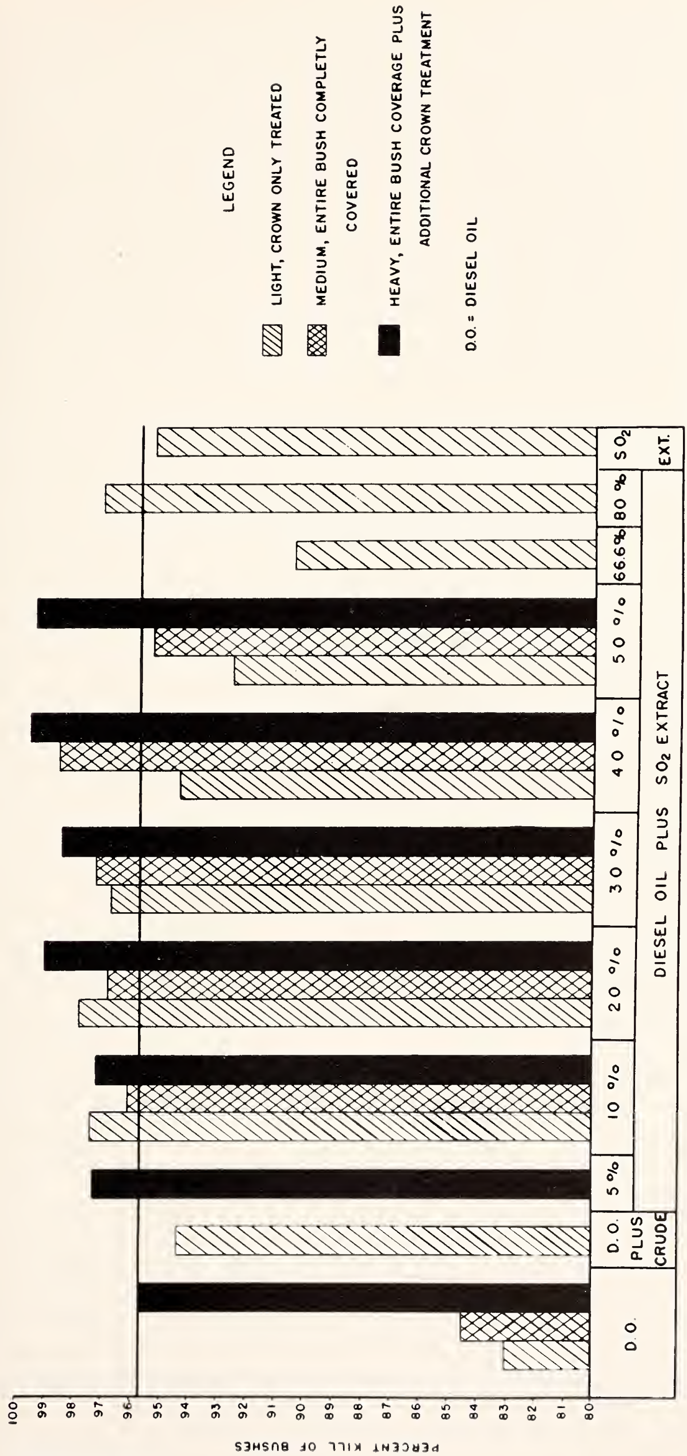

FIGURE 2.—Comparison of kill of *Ribes roezli* provided by several oil mixtures applied in light, medium, or heavy dosages.

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A comparison of similar treatments again shows that the addition of the sulfur dioxide extract increases the efficiency of Diesel oil; additions up to 40 percent by volume of the Diesel oil appear to improve bush kill. Although dosages for these selective treatments (table 3) cannot be compared directly with those for the uniform treatments (table 2), the medium dosage for the 1/40-acre plots approximates on a per-bush basis the 1.5 gallons per milacre dosage (table 2).

For the methods tests planned to compare the bush kill obtained by standard grubbing with kills resulting from oil sprays, a mixture of crude and Diesel oils blended to a specific gravity of about 27° Baumé

Table 3.—*Effectiveness of oil sprays selectively applied to* Ribes roezli *on Chowchilla Mountain Sierra National Forest, Calif., 1938*

Date applied and dosage	Oil used per plot	Sulfur dioxide extract added to Diesel oil	Bushes treated	Bushes killed
Unmeasured plots				
	Gallons	*Percent*	*Number*	*Percent*
July 24–28:				
Heavy	30	50	1,065	100
Light	9	44	930	97
	5	[1] 100	400	83
	15	[2] 0	1,500	94
1/40-acre plots				
Aug. 3:				
Heavy	9	10	508	97
Medium	5		425	96
Light	7.5		550	97
Heavy	8.5	20	490	99
Medium	8		650	97
Light	7.5		580	98
Heavy	15	30	900	98
Medium	9		640	97
Light	14		812	97
Heavy	12	40	720	99
Aug. 4:				
Medium	5	40	380	98
Light	7.3		571	94
Heavy	10	50	500	99
Medium	9.5		710	95
Light	5.5		331	92
Heavy	6.5	[3] 0	300	96
Medium	8		560	84
Light	8.5		552	83
Heavy	4	5	240	97
Light	4	66	257	90
	3	80	300	97
	4	[1] 100	310	95

[1] Sulfur dioxide extract alone.
[2] Diesel oil and light crude oil (1:1).
[3] Diesel oil alone.

was chosen on the basis of low cost, toxicity, and availability. Three oil-treated plots from about 12 to 28 acres were compared with plots of 5 to 100 acres grubbed by the standard procedure. This work was also done on Chowchilla Mountain. Typical sites and growth forms for the young *roezli* bushes and the appearance of the soil about the treated bushes are shown in plate 2.

On the three oil-treated plots, 95, 84, and 50 percent of the bushes were killed. These figures are based on bushes that were missed as well as those that the oil failed to kill. Bush kill by grubbing ranged from 51 to 95 percent for comparable plots. The low percentages of kill for both methods were associated with heavy brush that made ribes difficult to find.

The primary interest in these tests was the comparative man-day cost of chemical and grubbing work as summarized in figure 3. The

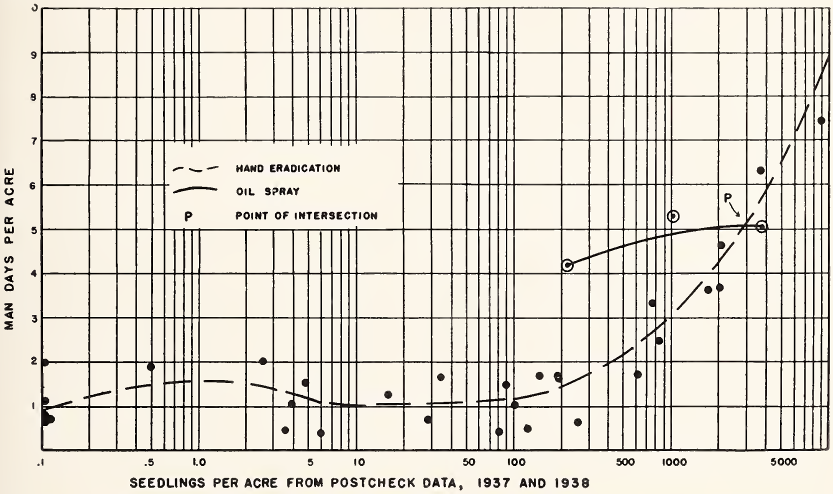


FIGURE 3.—Comparison of man-days required for oil-spray and hand-eradication work on *Ribes roezli* seedlings.

post-check data represent a count of *roezli* seedlings made on a line transect basis amounting to a sample of 10 percent of the area. Costs of oil and grubbing work expressed in man-days per acre show that oil treatment is more economical than grubbing when populations of young ribes bushes exceed 3,000 per acre. The curve shown for the oil treatment includes the cost of oil expressed in terms of man-days per acre.

CHLORINATED PHENOXY COMPOUNDS

The herbicidal properties and uses of chlorinated phenoxy compounds and related chemicals have been reviewed in previous publications (Blackman *1*, Crafts and Harvey *2*, Evans *et al.*, *6*, Kraus and Mitchell *8*, Lucas and Hamner *10*, Offord *18*).[6] Properties and uses of 2,4-D and 2,4,5-T will be discussed in this circular only insofar as they relate to the ribes-eradication problems.

[6] The June 1946 issue of Botanical Gazette contains 18 papers in the herbicidal properties of plant growth-regulating substances. These papers summarize the studies in this field undertaken at Camp Detrick, Md., by the Chemical Warfare Service.

In November 1943, before the chlorinated phenoxy compounds were available, some exploratory tests of growth-regulating substances as possible herbicides for ribes control were made at Berkeley on duckweed (*Lemna minor* L.) Included were indole-3-acetic acid, alpha-naphthaleneacetic acid, indole-3-propionic acid, phenylacetylene, and triphenyl-acetic acid. Each of these compounds was tested alone and in combination with sodium chlorate and with ammonium sulfamate. All these chemicals showed marked phytocidal properties.

2,4-D acid was first tested as a herbicide on ribes in December 1944. These tests, also at Berkeley, were made on 2-year-old greenhouse-grown *roezli*, and included foliage sprays and soil treatments with the acid in polyethylene glycol, and with the triethanolamine salt of 2,4-D. These materials were also tested separately in combination with ammonium sulfamate. The 2,4-D acid and amine salt sprays at concentrations of 800 p. p. m. of the acid equivalent killed all 10 plants in two series of preliminary tests. Combinations of 2,4-D and ammonium sulfamate were equally effective.

As events subsequently showed, the selection of *roezli* as the test plant was a fortunate one, because this species is unusually sensitive to 2,4-D. At that time nothing was known about the high selectivity in the phytocidal action of 2,4-D, especially on closely related species within a genus. Had the first tests with 2,4-D been made only on *lacustre*, a species highly resistant to 2,4-D, this new herbicide might not have received the early attention that it did in blister-rust control.

Although 2,4-D was available only in laboratory-scale quantities early in 1945, enough material was obtained to make small field trials in California, Oregon, and Idaho on *binominatum*, *cereum*, *cruentum*, *erythrocarpum*, *inerme*, *lacustre*, *lobbi*, *montigenum*, *nevadense*, *petiolare*, *roezli*, *sanguineum*, and *tularense*. Only *cereum*, *nevadense*, *petiolare*, and *roezli* appeared to be sensitive to aqueous solutions of 2,4-D salts or esters, or to 2,4-D acid in polyethylene glycol.

Most of the chemicals and mixtures listed under Miscellaneous Compounds and Chlorinated Phenoxy Compounds were tested from 1945 through 1949 in an attempt to find another organic chemical that would be as effective on all species of *Ribes* as 2,4-D had proved to be on the four species just noted. Preliminary tests with 2,4,5-T, made at Berkeley in 1946–47, showed that it was much less specific than 2,4-D in its toxicity to ribes. Greenhouse-grown plants of *binominatum*, *inerme*, *lacustre*, *lobbi*, *sanguineum*, and *vicosissimum* were killed by the aqueous solution of the sodium salt and the isopropyl ester of 2,4,5-T in concentrations of 2,000 p. p. m. or more of the acid equivalent: these species could not be killed economically with 2,4-D. From 1947 through 1949 these observations were confirmed by extensive field tests with 2,4,5-T in Oregon, Washington, Idaho, Wyoming, and Colorado.

In developing practical methods for the use of 2,4-D and 2,4,5-T in ribes eradication all the factors noted on page 4 were studied either in the laboratory or greenhouse or in the field. Of these factors species variation in susceptibility, age and vigor of the ribes, seasonal development of the plants at the time of treatment, and the type of vegetation associated with the ribes have most strongly influenced the effectiveness of 2,4-D and 2,4,5-T. Other problems such as resprouting bushes, effectiveness on soil-stored ribes seed, and equipment needed for making the approved treatments have been studied

A, Oil crew at work on *Ribes roezli* seedings, Sierra National Forest, Calif. Note the manner in which the *Ceanothus* bush must be inspected to detect ribes seedlings underneath. *B*, Three-gallon compressed-air sprayer. *C*, Heavy patch of young *roezli* just after oil treatment.

in the greenhouse and field. The general significance of many of these factors has already been discussed for the use of 2, 4-D applied as a foliage spray to *roezli* (Offord *18*). In this circular data from field plots will be used to show how the properties and uses of 2,4-D and 2,4,5-T are related to practical problems of ribes eradication.

Species Variation in Susceptibility.—*Ribes* species vary markedly in their response to the phytocidal action of the chlorinated phenoxy compounds. The monochlorophenoxyacetic acid is more specific than its dichloro analog, which in turn is more selective in its toxicity to ribes than the trichlorophenoxyacetic acid. From 1944 through 1949, commercial formulations of 2,4-D and 2,4,5-T were tested on 33 species of native *Ribes*. All the species listed on pages 6 to 9 can be damaged by thorough coverage of leaves and stems with aqueous sprays containing the ester of 2,4,5-T. Comparable dosages of 2,4-D will cause major systemic damage to only 5 species. Monochlorophenoxyacetic acid has not been tested so thoroughly as 2,4-D and 2,4,5-T, but it caused major systemic damage to only 3 of the 11 species on which it has been used.

For the *Ribes* species sensitive to 2,4-D the minimum lethal concentration and dosage of this herbicide is lower than that of 2,4,5-T. Mature, vigorous specimens of *bracteosum* and *roezli* have been killed with foliage sprays of aqueous solutions of 2,4-D containing only 75 p. p. m. of the equivalent acid. The minimum effective concentration of 2,4,5-T on sensitive ribes is about 500 p. p. m., and for most ribes a concentration of at least 2,000 p. p. m. seems to be needed for satisfactory kill. In comparison with 2,4-D the phytocidal action of 2,4,5-T is slower and less affected by the growth stage of the ribes. The slow-killing action of 2,4,5-T is most clearly shown in mid-season and late-season treatments. Although the cambium of basal stems and root crowns may still look healthy during early season of the following year, ribes bushes treated with 2,4,5-T usually fail to form new leaves or to sprout from the crown. In contrast, ribes showing fresh basal stem and root crown the spring after being treated with 2,4-D usually sprout vigorously and continue to grow. From these observations it may be concluded that 2,4,5-T has a more persistent residual effect than 2,4-D.

With the exception of the black currants, which are highly susceptible to 2,4-D, the classification of currants and gooseberries by subgenera or by gross morphologic criteria does not consistently indicate susceptibility to the phenoxy compounds. Surface characteristics of leaf and stem have called for some variation in the amount of spreader and marker, but the fundamental action of 2,4-D or 2,4,5-T seems to be related to physiological rather than morphological characteristics of the ribes.

Effect of Seasonal Development and Age of Plants.—Aside from the sensitivity of the *Ribes* species to the phenoxy herbicides the factors that most consistently and significantly affect the kill of the bushes are the age and seasonal development of the plants at the time of spraying. The two curves in figure 4 show the difference in susceptibility of young and old *roezli* to sprays containing 720 p. p. m. of 2,4-D. Data are noted on figure 4 for plots showing results widely divergent from the kill obtained with this concentration on an average mixed-age-class population of *roezli*. Age and vigor of growth are especially significant for a plant such as *roezli* that occurs in up-

land sites in a region where summer rains do not add importantly to soil moisture. *Ribes roezli* has a short period of unusually vigorous growth when it is possible to kill 80 percent or more of the old plants and 95 percent or more of the young plants with one spraying.

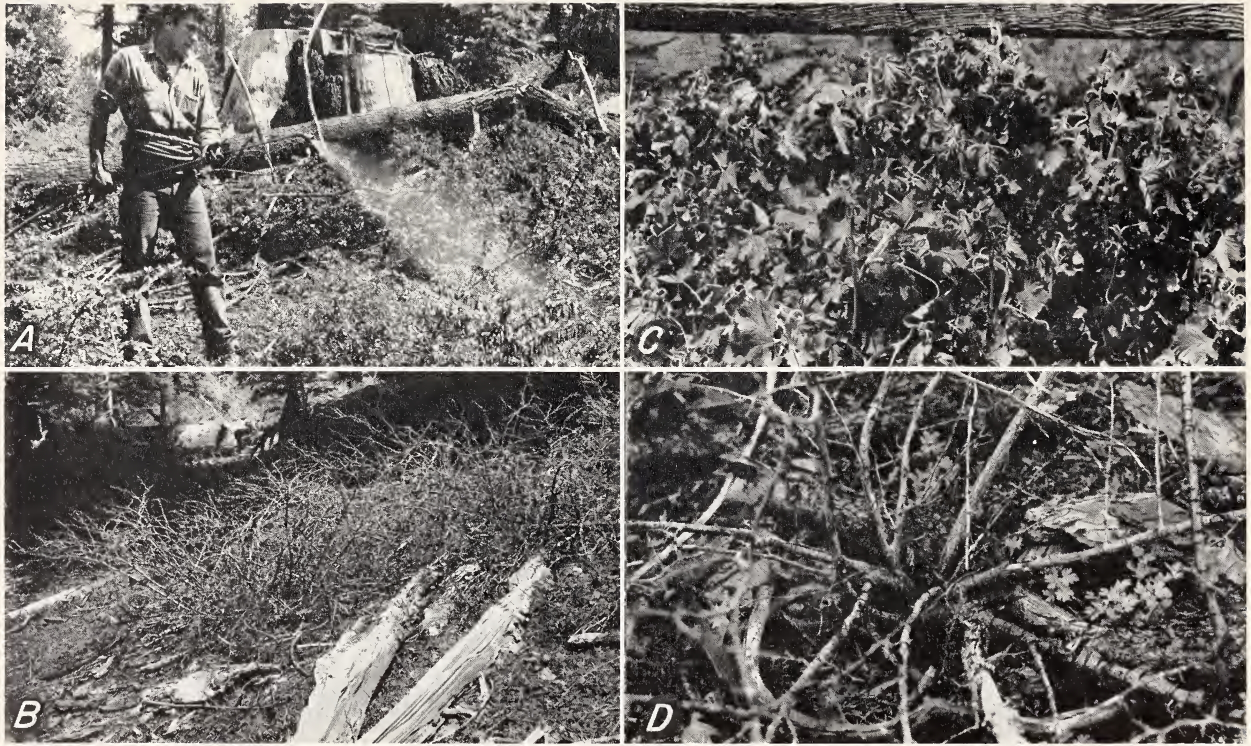
In tests on the effectiveness of 2,4-D sprays on ribes in various stages of growth, the bush kill was based on the total number of bushes treated in a year for comparable methods of spraying. The results were averaged for all plots where no consistent or significant differences occurred for the range of concentration shown. Results for aqueous solutions of salts and esters are combined. Oil sprays contained esters only.

A summary of all data for spray tests on *roezli* and *nevadense* shows bush kill sharply reduced by spraying before or after the period of active growth (table 4). Furthermore, late-season (past-active stage) differences are more marked for upland *roezli* than for *nevadense*. The latter species occurs along the margin of streams or in moist, cool sites, where the plants make slow but continuous growth under ecologic conditions that do not show the extreme variations of the typically dry upland, where *roezli* is found. Foliage kill with 2,4-D is slower and less uniform on *nevadense* than on *roezli*, although epinastic response of petioles and young stem tissue of *nevadense* is somewhat marked (pl. 3, *C*).

Results of spraying *lacustre* and *viscosissimum* with 2,4,5-T did not show variation in bush kill for three stages of growth to the same degree shown for *roezli* in table 4. By the middle of August it was necessary to use 2,4,5-T at a concentration of about 3,000 p. p. m. to obtain the 100-percent kill that had been achieved with 1,500 p. p. m. during June and early July. Nevertheless, a satisfactory kill can be obtained from early June to late August merely by increasing the dosage. The principal reason for this is probably the steadier and longer growth period of these two species in northern Idaho, where soil moisture throughout the summer is more abundant than in sugar pine areas of California. There are indications, from seasonal tests on several *Ribes* species, that the phytocidal action of 2,4,5-T is not affected by the growth stage of the plant to the same degree as is 2,4-D, but this observation needs to be clarified by further study.

The importance of correlating data on bush kill with the age and the seasonal development of ribes treated with 2,4-D is clearly shown (tables 4 and 5) by the variations in the percent of bushes killed. This percent in table 5 is based on the total number of bushes sprayed from 1946 through 1948 for various concentrations and types of 2,4-D product. All tests are for comparable spray treatments, mostly 10 gallons per square rod. Results are somewhat erratic if measured by the type of 2,4-D, the diluent used, and the concentration of the active ingredient. When the ribes plants are of a similar age and seasonal development, with a few exceptions, results are fairly consistent even for the treatments made in different years. Ribes bushes in dense brush have been difficult to kill by one spraying with 2,4-D, especially if it is done when plants are past their active-growth period. Practically all top growth of brush-type ribes is killed by the initial spray, but resprouting from the root crown is general the following year.

Age of the plant is probably next in importance to seasonal development in affecting susceptibility of ribes to 2,4-D and 2,4,5-T. In several hundred greenhouse tests on 2- or 3-year old *roezli* all the bushes



A, Typical patch of *Ribes roezli* on cut-over land being sprayed with amine salt of 2,4-D. *B*, Similar patch 1 year later; all bushes in this patch are dead. *C*, Epinasty in petioles and stems of *Ribes nevadense* 2 weeks after being sprayed with 2,4-D. *D*, *Ribes roezli* seedlings under parent bush killed by 2,4-D spray applied early in the season of the previous year.

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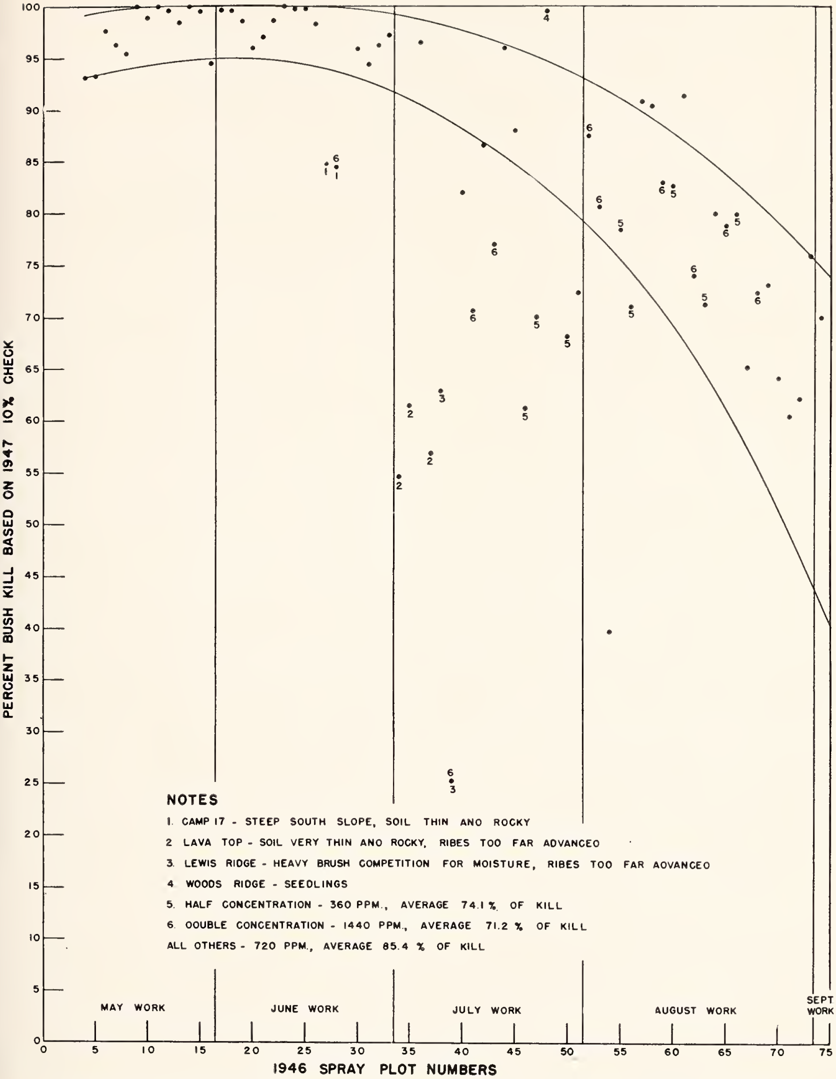

FIGURE 4.—Seasonal variation in effect of 2,4-D sprays on *Ribes roezli.*

were killed by aqueous sprays of 2,4-D containing 100 p. p. m. or more of the acid. A similar result was obtained under field conditions in spraying young *roezli* (less than 5 years of age). Ribes of intermediate age (5–10 years) are vigorous, mature, fruit-bearing plants and they also can be readily killed when sprayed during the period of vigorous growth (tables 4 and 5). The effective spray season is usually a month longer on young *roezli* and *nevadense* than on the older, more mature plants. Throughout the season the kill obtained on slow-growing plants over 10 years of age is less than that obtained on the younger plants. Deeply buried root crowns, layered stems,

TABLE 4.—*Effectiveness of 2,4-D sprays on* Ribes roezli *and* nevadense *in various stages of growth. California, 1945–48*

Ribes roezli

Growth stage and average age of treated plants in years	Concentration [1]	Diluent	Percent of bushes killed			
			1945	1946	1947	1948
Commencing:						
10+	250–2,000 p. p. m.	Water			37	
	0.9–18 percent	Oil			26	
5 to 10	750 p. p. m.	Water	70			
Active:						
10+	250–2,000 p. p. m.	Water	82		83	81
	0.9–18 percent	Oil			86	96
5 to 10	250–2,000 p. p. m.	Water	98	93	93	
	0.9–18 percent	Oil			82	
Past active:						
10+	250–2,000 p. p. m.	Water	43	15	23	49
	0.4–16 percent	Water			79	71
	0.9–18 percent	Oil				71
5 to 10	250–2,000 p. p. m.	Water	56	45	65	
	0.8–8 percent	Water		66	81	

Ribes nevadense

Growth stage and average age of treated plants in years	Concentration [1]	Diluent	1945	1946	1947	1948
Commencing:						
10+	18 percent	Oil			50	
	4 percent	Water			31	
5 to 10	500–750 p. p. m.	Water	75			
Active:						
10+	250–2,000 p. p. m.	Water	100		100	100
	0.9–9 percent	Oil				100
	0.8–16 percent	Water			99	93
5 to 10	250–2,000 p. p. m.	Water		100	100	
	0.9–9 percent	Oil			100	
Past active:						
10+	250–2,000 p. p. m.	Water			44	88
	0.9–18 percent	Oil			77	
	0.4–8 percent	Water				79
5 to 10	500–750 p. p. m.	Water	92	84		
	1.6–4 percent	Water		92		

[1] Concentration means acid equivalent in parts per million for dilute sprays and in percent for the more concentrated sprays in water or oil.

generally low physiological activity, and sparse foliage combine to reduce the efficacy of 2,4-D to old ribes plants.

FORMULATION AND DOSAGE.—With exceptions to be noted later, field tests (table 5) have shown that the several salts and the butyl ester of 2,4-D are about equally effective on *roezli* when used at dosages and concentrations represented by the range of 250 to 2,000 p. p. m. of acid equivalent. For a highly sensitive plant such as *roezli*, noticeable variation in bush kill of 10 percent or more for aqueous sprays of the salts and esters can be attributed to the ecologic type of ribes, its seasonal development, or its age rather than the type of 2,4-D product or its concentration.

TABLE 5.—*Effectiveness of 2,4-D at different acid equivalent concentrations when applied as aqueous sprays to* Ribes roezli *in various stages of growth. California, 1946–48*

Growth stage of bush treated with salt or ester of 2,4-D	Tests	250–360 p. p. m.		500–720 p. p. m.		1,000–2,000 p. p. m.	
		Bushes treated	Bushes killed	Bushes treated	Bushes killed	Bushes treated	Bushes killed
	Number	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Young, active bushes:							
Sodium	54	163	91	96	94	100	95
Triethanolamine		22	100	19	100	56	100
Ammonium		87	98	100	99	91	84
Butyl ester		154	88	185	94	0	-----
Totals and means	-----	446	92	400	95	247	92
Old, active bushes:							
Triethanolamine	19	36	72	34	82	57	88
Butyl ester		35	94	20	80	53	83
Totals and means	-----	71	83	54	81	110	85
Young, past-active bushes:							
Sodium	61	30	70	52	58	38	39
Triethanolamine		60	48	74	38	66	33
Ammonium		120	39	131	53	137	54
Butyl ester		25	36	41	29	48	50
Total and means	-----	235	45	298	47	289	47
Old, past-active bushes:							
Triethanolamine	19	16	56	19	53	30	43
Ammonium		30	53	36	22	84	20
Totals and means	-----	46	54	55	33	114	26

Thus far 2,4,5-T has been prepared commercially only in the ester form. By comparison with the ethyl, isopropyl, or butyl products no striking differences are apparent from the results of 1 year's tests with low vapor pressure esters (butoxyethanol) of 2,4,5-T and 2,4-D when these herbicides are applied as aqueous sprays in large volume. For small volume and low residue treatments the butoxyethanol ester and similar products appear to be somewhat better than the more volatile esters.

Spray tests with 2,4,5-T, 2,4-D, and mixtures of the two were made on *lacustre* and *viscosissimum* in northern Idaho from 1946 through 1949. Aqueous sprays containing 2,4,5-T were applied with a knapsack trombone sprayer at the rate of 1 gallon per milacre. The 2,4-D sprays at 5,000, 10,000 and 20,000 p. p. m. were applied selectively to ribes as a concentrate in oil with a high-pressure knapsack sprayer. For all tests foliage, stems, and root crown were sprayed thoroughly, and treatment was made at a favorable time in the growing season. The results are given in table 6. The 5,000 p. p. m. concentration of 2,4-D in oil killed just 2 percent of the *lacustre*. The satisfactory

bush kill (over 95 percent) of both species obtained with 1,500 p. p. m. or more of 2,4,5-T is in marked contrast to the poor bush kill obtained with much higher concentrations of 2,4-D. Except for seedling plants, only a few *lacustre* bushes were significantly damaged by sprays containing as much as 10,000 p. p. m. of 2,4-D. On *viscosissimum* 2,4-D is more effective than on *lacustre*, but it falls short of providing a satisfactory kill even in concentrations of 20,000 p. p. m. The addition of 2,4-D appears to interfere with the phytocidal action of 2,4,5-T on these resistant ribes. Because 2,4-D is cheaper, considerable effort has been made to test combinations of 2,4-D and 2,4,5-T as a substitute for 2,4,5-T alone. However, for operations spraying of *lacustre* and *viscosissimum*, 2,4,5-T alone is still recommended.

Twenty-seven tests (nine in each of three different areas) were made to compare the effectiveness of heavy, medium, and light treatments of 2,4-D sprays applied by a power sprayer for late-season work on *roezli*. For each treatment concentrations of 1,000, 500, and 250 p. p. m. of acid equivalent were employed. Light treatment means all foliage and stems were wet thoroughly to the ground line. Medium treatment means all foliage and stems were wet thoroughly to ground line plus auxiliary wetting of root crown. This is the procedure usually followed in large-scale field work. Heavy treatment signifies the same type of coverage as the medium treatment plus a heavy drench of the soil about all root crowns. The ammonium salt was used for bushes on the Plumas National Forest and the triethanolamine salt for bushes on the Sierra National Forest, both in mid-July 1947. The sodium salt plus a sticker-spreader plus a summer oil emulsion was applied on August 5 to 8, 1948, also on the Sierra. Approximate volume of spray solution used in the heavy, medium, and light treatments was at the ratio of 4 : 2 : 1. There was a dosage ratio of approximately 16 : 1 between the heavy 1,000 p. p. m. and the light 250 p. p. m.

Table 6.—*Effectiveness of 2,4-D, 2,4,5-T, and mixtures of the two on* Ribes lacustre *and* viscosissimum *in northern Idaho, 1946–49*

Herbicide	Concentration of acid equivalent	Bushes killed	
		Ribes lacustre	*Ribes viscosissimum*
	P. p. m.	*Percent*	*Percent*
2,4-D	5,000	2	16
	10,000	5	44
	20,000	12	63
2,4,5-T	500	72	89
	1,000	78	99
	1,500	100	100
	2,000	98	99
	3,000	97	100
	4,000	97	100
2,4-D plus 2,4,5-T	500 + 500	40	44
	1,000 + 500	43	74
	500 + 1,000	56	82
	1,000 + 1,000	73	95
	2,000 + 1,000	44	82

In the following instances noticeable differences in bush kill seem to be related to formulation. On old *roezli* bushes the formulation containing 250 to 1,000 p. p. m. of acid equivalent of the sodium salt of 2,4-D plus 10,000 p. p. m. of summer oil emulsion plus 400 p. p. m. of a sticker-spreader was superior to the amine or ammonium salt (250 to 1,000 p. p. m.) without the summer oil emulsion. Bush kill exceeded 90 percent in all treatments for the summer oil formulation, whereas the bush kill was 7 to 46 percent for the ammonium salt and 23 to 39 for the triethanolamine salt. Subsequent tests have not always shown such a large difference, but the addition of summer oil to 2,4-D and 2,4,5-T sprays has improved the kill by 15 to 30 percent. Tests made on the Sierra National Forest in mid-July 1950 also indicate that propylene glycol, 1 percent by volume, improves the phytocidal action of 2,4-D sprayed late in the season or under arid conditions.

Light dosages were less effective on *roezli* on the Plumas National Forest than on the Sierra National Forest. Bush kills of 17, 25, and 7 percent on the Plumas plots reflect unfavorable seasonal development of the bushes and, more important perhaps, a varietal form of *roezli* that is difficult to kill with 2,4-D.

On the Plumas National Forest *roezli* approaches the northern extreme of its distribution where it begins to resemble *cruentum*, which is much more resistant to 2,4-D. In this northern range as much as 25 percent of the population of mature *roezli* have shown unusual resistance to 2,4-D. (Unless clear-cut varietal forms of a *Ribes* species are involved, the percentage of resistant individuals within a population of a highly susceptible species does not usually exceed 5 percent.) For *roezli* on the Plumas National Forest and other areas of the Sierra Nevada from Lake Almanor north a mixed spray containing 500 p. p. m. of 2,4-D and 1,000 p. p. m. of 2,4,5-T plus 10,000 p. p. m. of summer oil has been about 20 percent better than the standard formulation of 2,4-D alone. Of the many *Ribes* species on which mixtures of 2,4-D and 2,4,5-T have been used, this northern variety of *roezli* is the only one for which the mixture has been superior to an equivalent amount of either material alone.

Importance of Thorough Coverage.—Thorough coverage of all leaves, stems, and adventitious buds from the terminal leaves to the basal part of stems at ground level is necessary for uniform high-percentage kill. *Ribes roezli* sprouts vigorously from the root crown unless all potential growing points are destroyed with the 2,4-D. The number of adventitious buds and the manner in which they occur about the crown of *roezli* and *lacustre* are shown in figure 5. Some of these buds may be located on part of the crown that is not connected with an active leaf-bearing stem, and it is from this part that a sprout may arise. Wetting the upper part of the root crown with 2,4-D will often stop these sprouts from developing.

When 2,4,5-T is applied to *lacustre*, a species not readily damaged by 2,4-D, it is especially important to wet all adventitious buds on the lower part of the stems and about the crown. When any species of *Ribes* is sprayed, care must be taken to cover the growing tips of all branches and to direct the spray over the plant from at least two opposing sides. Tall, straggling plants are more difficult to spray properly than are low, compact plants. Fully foliated plants generally are killed more readily than are plants with sparse foliage.

FIGURE 5.—*A*, Numerous adventitious buds about the periphery of the root crown of *Ribes roezli*. Buds often are protected by the form of the root crown and stems. *B*, Position on basal stem and root crown of *lacustre* from which adventitious buds originate. It is essential that the spray solution reach these parts of the root crown.

EFFECT OF WEATHER ON KILLING ACTION.—Light, temperature, and relative humidity affect the rate of killing action of 2,4-D, but the final bush kill remains about the same for ribes plants sprayed at the same stage of seasonal development. Extreme variations in these factors might reduce photosynthesis and reduce downward movement of carbohydrate below certain critical levels and be reflected in poor bush kill. In the field, however, heavy shade means association of the ribes with trees or shrubs, and it has been difficult to attribute the primary cause of poor kill to shade or to the effects of plant competition. Ribes in the shade of trees has not been noticeably hard to kill, but ribes associated with dense shrubs has been. Rain within a half-hour of application seems to have little effect on the toxicity of 2,4-D and 2,4,5-T esters. However, heavy rains within an hour or so may reduce the killing power of dilute aqueous solutions (2,000 p. p. m. or less) of the highly soluble ammonium and amine salts. The mixed titanium dioxide (30 percent) and barium sulfate (70 percent) marker used at the rate of 1½ pounds of marker for each 100 gallons of spray solution for ribes eradication shows most clearly when sprayed onto dry foliage. The same is true of the summer oil emulsion used as a combination marker and penetrant.

An analysis of all plot records (1945–49) on spraying *roezli* with 2,4-D shows no consistent correlation between the time of day when spraying was done and the percent of bushes killed. For this analysis results of spray tests were grouped into classes for hourly intervals between 8 a. m. and 4 p. m.

SUSCEPTIBILITY OF CROWN SPROUTS.—Crown sprouts and partly killed bushes must also be sprayed during the season of high suscep-

tibility. This period begins about 2 weeks later in the spring than for plants not previously sprayed, and continues as long as the sprouts show vigorous growth. In 1947–48 several plots having *roezli* crown sprouts were resprayed with aqueous solutions containing 250 to 2,000 p. p. m. of 2,4-D. One year after respray 90 percent of the crown sprouts were dead. Low-volume spraying of similar crown sprouts with an aqueous solution containing 2 percent of the amine and with 2 percent of the ester in oil gave 89 and 98 percent kills. In similar tests on crown sprouts at the past-active growth stage the kill was 74 percent. Thirteen plots of *nevadense* on which oil and water concentrates had been used showed a 100-percent kill of crown sprouts.

Crown resprouts and partially killed bushes can usually be attributed to one or more of the following: (1) Failure to treat during the susceptible period of growth, (2) failure to get complete coverage of all stems and leaves, (3) genetic and varietal differences of individuals in a population of susceptible species, (4) sublethal dosage, and (5) general low susceptibility of the species to the phenoxy sprays.

Rechecking of 2,4-D-treated ribes the second season showed some die back of crown sprouts that were recorded as alive at the first growing season after the parent bush had been sprayed. This phenomenon was noticed especially for old bushes initially sprayed during the active-growth period. For a series of 19 plots on which 235 *roezli* plants had been sprayed in 1947 with a solution of 2,4-D containing from 250 to 2,000 p. p. m. of 2,4-D, the bush kill was 83 percent in 1948 and 92 in 1949. On crown sprouts appearing the year after the old stem has been killed by the sprays, the foliage is often noticeably modified in a manner typical of growth-regulating substances (fig. 6). These responses indicate the presence of 2,4-D or its effect on plant tissue a year after treatment.

Effect on Seed Viability.—The viability of ribes seed is destroyed by low concentrations of 2,4-D or 2,4,5-T. Ribes seeds are hard-coated and will retain their viability through several weeks of immersion in many of the inorganic acids, alkalies, and plant poisons. In tests undertaken by C. R. Quick in the greenhouse at Berkeley immersion of unplumped *roezli* seeds for 24 hours in aqua regia (hydrochloric plus nitric acid) containing about 15,000 p. p. m. of total acid reduced germination of seed to 79 percent from a normal of 90 percent. In parallel tests an equal immersion in 1,000 p. p. m. of 2,4-D acid resulted in only a 14-percent germination, and immersion for 48 hours in 200 p. p. m. prevented germination. Immersion of dry seeds in 60 p. p. m. of 2,4-D for 4 days reduced germination to 1 percent. Germination tests on other *Ribes* species showed that the sensitivity of seeds to various chlorinated phenoxy compounds was correlated closely with the sensitivity of the mature plant to the killing action of the same chemicals.

Numerous *roezli* seedlings sometimes grow under the parent plant killed the previous year by 2,4-D sprays applied in May and June (pl. 3, *D*). In contrast, killing of mature *roezli* in mid-July and August by 2,4-D sprays or dormant treatments with the concentrate of 2,4-D ester in oil have resulted in little or no establishment of seedlings a year later. Nevertheless, over most of the acreage thus far sprayed with 2,4-D and 2,4,5-T ribes regeneration has been less from soil-stored seed than has followed grubbing. Comparable areas

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grubbed in earlier years showed heavier and more persistent seedling regeneration than has been the case with chemical treatments.

There is no evidence that a seedling population from parent plants treated with these herbicides has acquired any resistance to them.

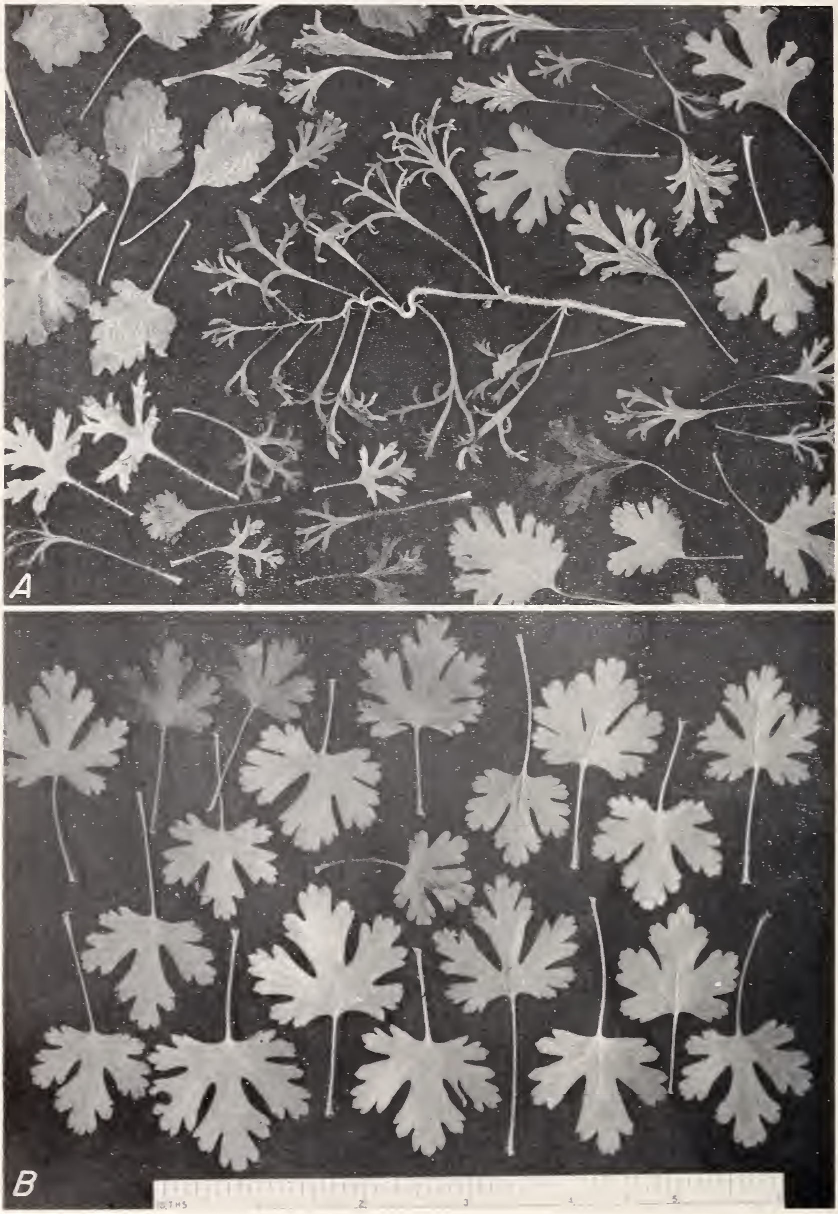


FIGURE 6.—*A*, Modification of *Ribes roezli* leaves, petioles, and current-season shoots caused by 2,4-D. These specimens taken from partially killed mature plants 1 year after being sprayed with an aqueous solution of 2,4-D. *B*, Typical leaves of *roezli* from untreated greenhouse plants.

In the Stanislaus National Forest, several acres of 3-year-old *roezli* were sprayed in 1949 with 250 p. p. m. of 2,4-D resulting in nearly 100-percent kill. These seedling ribes were established after the death of the parent ribes sprayed with 2,4-D in 1946.

Although low dosages of 2,4-D and 2,4,5-T are effective on ribes seed, it does not seem to be economically feasible to broadcast sufficient herbicide in the regular spraying operation to destroy all soil-stored seed. Regeneration is spotty and often unpredictable because of extreme variability in mountain soils. Newly established ribes are easy to kill and can be readily sprayed on a subsequent working.

Effects of Soil Type.—The ease with which ribes can be killed by 2,4-D and 2,4,5-T is related in part to the physical character of the soil, to the relationship between soil type and water retention, and to the extent to which these factors determine growth vigor. Soil-moisture characteristics of mountain soils, as expressed by the moisture equivalent and the permanent wilting percentage, can vary significantly in forested areas that support generally similar vegetative types. To obtain moisture data on mountain soils typical of the Sierra Nevada 28 samples from various locations were collected by discarding surface litter and taking shovel depths of the top soil from a surface area of about 1 square rod. Each sample was reduced in size by mixing on a piece of canvas and quartering until about 2 gallons of well-mixed soil was available. These samples represent the layer of top soil in which most of the active roots of *roezli* occur, but the individual samples were not separated by soil horizons in the accepted terminology of soil scientists. The moisture equivalent was determined according to the centrifuge method and the permanent wilting percentage according to the dwarf sunflower culture, both as described by Piper (*21*, pp. 89–96).

Data in table 7 show that the permanent wilting percentage of Sierra Nevada soils supporting populations of *roezli* can range from 5.1 to 22. The free or available soil water is expressed by the ratio of moisture equivalent to permanent wilting percentage and for these samples this ratio ranged from 1.5 to 2.8.

The capacity of the soil to absorb and retain water certainly affects the length of time that vegetation can continue to make vigorous growth. A shallow soil of low capacity for water retention will mean a short growing season for ribes, especially for *roezli*, in the mixed-conifer type of the Sierra Nevada, where summer rains are rare.

The six soil samples taken from the vicinity of Cow Creek, Stanislaus National Forest (table 7), were further analyzed. The principal nutrient constituents were determined by the microchemical method of Peech and English (*20*, pp. 167–195) and the organic carbon by the method of Walkley and Black (*24*, pp. 29–38). The average green weight per seedling of those surviving at the end of 5½ months from an original planting of 10 seedlings was also determined. These results, as given in table 8, confirm the high variability of mountain soils and show the degree to which poor soils low in available water and nutrients affect the growth rate and vigor of *roezli*. The two highest green weights of test seedlings (2.1 and 1.4 grams per plant) are associated with the highest levels of nitrogen and organic carbon. The one alkaline soil of this series had a high calcium content of 900 p. p. m. and a pH of 7.4. This sample was taken from an area that had been burned over 2 years before. This

TABLE 7.—*Moisture data for 28 samples of soil taken from the mixed conifer type of the Sierra Nevada, Calif., July 1938*

Location	Moisture equivalent	Permanent wilting percentage	Available soil-water (ratio)
Sierra National Forest, Chowchilla Mountain	26.5	13.5	2.0
	22.3	10.0	2.2
	30.9	12.0	2.6
	33.9	15.4	2.2
	44.6	22.0	2.0
	34.1	17.7	1.9
Stanislaus National Forest:			
Cow Creek	29.3	17.6	1.7
	25.6	13.9	1.8
	18.5	8.2	2.3
	15.1	6.1	2.5
	20.3	7.3	2.8
	18.5	8.2	2.3
Thompson Meadows	40.9	19.3	2.1
	30.3	14.7	2.1
	29.6	11.3	2.6
	40.6	20.1	2.0
	20.8	9.9	2.1
	30.5	13.2	2.3
Eldorado National Forest, Big Silver	31.6	15.6	2.0
	21.9	8.8	2.5
	21.7	10.3	2.1
	13.0	5.1	2.5
Plumas National Forest:			
Almanor	36.1	17.0	2.1
	29.7	19.5	1.5
	32.9	17.4	1.9
	33.7	11.8	2.8
Meadow Valley	36.6	21.0	1.7
	12.0	5.7	2.1

soil had adequate nutrient to grow ribes seedlings more vigorous than is indicated by an average seedling weight of 0.4 gram, but the pH of 7.4 is unfavorable for ribes growth.

Some of the *roezli* on recent burns had shown poorer kill than the age class of the plants warranted. Inactivation of 2,4-D by finely divided carbon (Lucas and Hamner *10*) may account in part for this reduced effectiveness where there is some root absorption of the herbicide. Variations in soil type might therefore account for some of the anomalies in bush kill noticeable over extensive areas that have been sprayed with 2,4-D or 2,4,5-T in regular operations work. Some greenhouse tests have indicated that ferric oxalate interferes with the phytocidal action of 2,4-D on *roezli*. It is possible, therefore, that this material might not be effective in highly ferruginous soils, though no consistent correlations on this point have been observed from experimental plots.

DECAPITATION TREATMENT

In 1932 a study was begun on the application of chemicals to the cut-off crowns of large rock-bound ribes plants and those difficult to dig or pull because of their rooting habits. By 1937 the chemicals

most widely used for decapitation work were a 5:1 mixture of powdered borax and sodium chlorate where a dry powder was needed, and Diesel oil where a liquid was favored, as described by Offord *et al.* (*19*). This publication summarized results of decapitation tests through 1936 and outlined in detail the procedures used in establishing plots, preparing the crowns for treatment, and recording plot data. It also showed the importance of making the cut either through the root crown or as close to it as possible. When all stems were removed from the root crown, it was recorded as having had a low cut. If an inch or more of stem was not removed (either intentionally or because the root crown was protected by rock or a stump), the test was recorded as a high cut. The significance of these terms has been retained in reporting data in tables 9 and 10.

From 1937 through 1939 decapitated ribes bushes in California and Oregon were treated with a mixture of common salt and borax, with oil, and with thiocyanate. All tests were made on low-cut plants or on root crowns from which all leaf-bearing stems had been cut. Results of these tests are given in table 9. Some exploratory tests (not shown in this table) were made to compare the dosage and effectiveness of ammonium sulfamate with those of ammonium thiocyanate. The two chemicals were found to be equally effective, and ammonium sulfamate (as Ammate) was used in operations work on the basis of previously published data for the thiocyanates (Offord *et al.*, *19*). The wide range of dosages shown in table 9 indicates the variation in the size of root crowns of ribes. Single root crowns having a diameter of about 1 inch required a minimum dosage of 1 ounce, whereas large multiple-rooted *cereum*, forming a dense clump, and large *nevadense* required heavier dosages.

In 1947–48 decapitation tests with 2,4-D and 2,4,5-T were made in California, Idaho, and Oregon. The results of these tests are given in table 10. The dosage of phenoxy compound applied to these test plants varied with the size of the crown (low cut) or the number of cut-off stems (high cut), being just sufficient to wet to the point of run-off all the freshly cut surface of the crown or the ends of the stems. No significant differences were noted for concentrations of the ester or amine ranging from 10,000 to 50,000 p. p. m. of acid equivalent. The choice between 2,4-D or 2,4,5-T for use on cut-off crowns is determined by the sensitivity of the species to foliage sprays. On crowns of *lacustre* 2,4,5-T was significantly more effective than 2,4-D. In oil or water 2,4-D was about equally effective on *roezli* and *nevadense* when bushes were cut off close to the crown.

The effectiveness of the decapitation treatment depends in part on the selection of the herbicide to meet the particular growth form of the plant and the conditions of the site, and in part on thorough coverage of the freshly cut surface of short stems or root crown. If the treatments are to be made primarily on large multiple-rooted bushes, liquid herbicides such as Diesel oil and concentrates of 2,4-D or 2,4,5-T in oil or water are most practical (pl. 4, *A*). For intermittent use on single-crown bushes (pl. 4, *C*) dry chemical has been favored by field men in several of the white pine regions (pl. 4, *D*).

To a large extent the use of herbicide in the decapitation treatment supplements damage done by cutting, thus minimizing the chance of sprouting from the cut-off crown. If a low cut is made through or just below the heavy bulbous part of the root crowns, many ribes

TABLE 8.—*Growth of* Ribes roezli *test plants, soil moisture, and nutrient constituents in six soils collected from mixed conifer type, Cow Creek, Stanislaus National Forest, Calif., July 1938*

Weight of ribes seedling (grams)	Germination of ribes seed	Moisture equivalent	Permanent wilting percentage	pH	Analysis (parts per million)									Organic carbon
					(NO^3)	(NH^3)	P	K	Ca	Mg	Fe	Al	Mn	
	Percent	*Percent*												*Percent*
2.1	74	25. 6	13. 9	6. 2	3	18	0. 5	25	360	4	0. 3	18	25	9. 4
1.4	81	29. 3	17. 6	5. 9	7	30	1. 0	40	400	14	. 2	15	40	12. 0
1.1	68	18. 5	8. 2	6. 2	1	16	. 7	20	280	4	. 7	20	28	7. 9
0.9	60	18. 5	8. 2	6. 1	1	14	1. 7	30	320	7	. 3	10	30	9. 8
0.4	69	20. 3	7. 3	7. 4	4	10	3. 0	25	900	10	. 2	15	30	5. 1
0.3	52	15. 1	6. 1	6. 2	Trace	12	. 4	10	200	50	Trace	4	3	. 9

TABLE 9.—*Effectiveness of dry and liquid herbicides applied to decapitated* Ribes *in California and Oregon, 1937–39*

Location and date of treatment	Chemical	Chemical per crown [1]	Species of *Ribes*	Bushes treated	Bushes killed
		Ounces		*Number*	*Percent*
California:					
Oct. 4, 1939	Common salt plus borax (1:1)	3½–27½	*roezli*	57	96
		3½–55	*nevadense*	9	100
		3½–20	*viscosissimum*	35	100
		3½–55	*cereum*	11	100
Aug. 5, 1937	Diesel oil	2–6	*roezli*	52	100
Sept., Oct. 1937		2–4	do	100	99
Oct. 14, 1937		2–17	*nevadense*	100	68
July 30, 1938	Diesel oil plus crude oil (1:1)	42–224	*cereum*	17	88
Oct. 12, 1937	Diesel oil plus furfural [2] (10:1)	1–5	*roezli*	100	100
	Diesel oil plus furfural [2] (7:1)	1–4	do	170	99
June 8, 1938	Sodium thiocyanate	1–8	*nevadense*	40	96
Oregon:					
Sept. 14, 1938	Ammonium thiocyanate	8	*bracteosum*	210	70
	Sodium thiocyanate	8	do	158	70

[1] Fluid ounces of Diesel oil and oil mixtures.
[2] Furfural was saturated with ammonium thiocyanate.

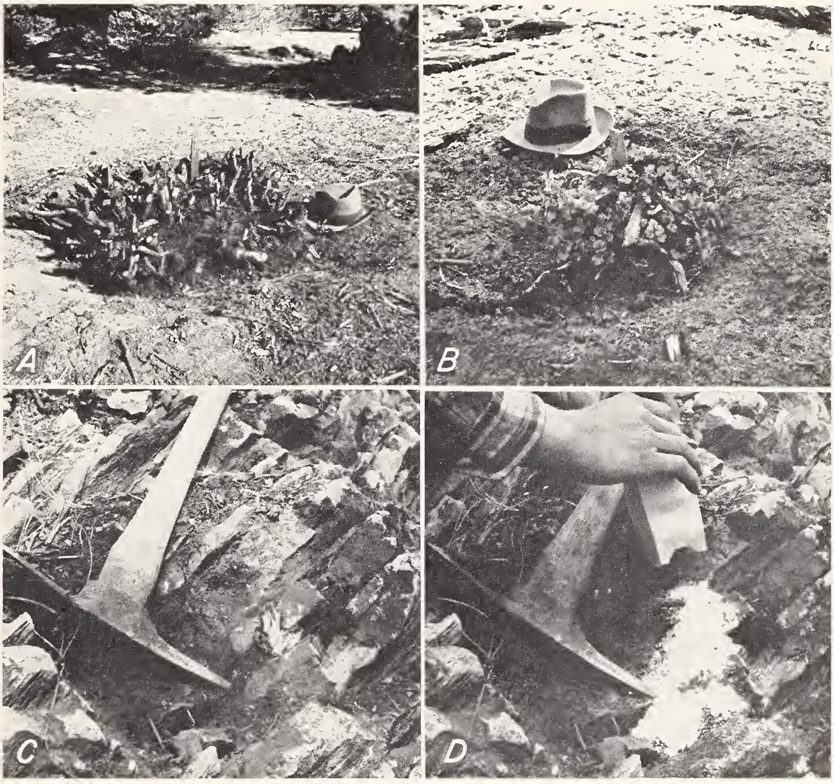
bushes will die during the ensuing fall and winter, especially the upland-type ribes. Accumulated data for untreated checks (no chemical applied) from previous experiments in California, Oregon, and Idaho (1932–46) showed an average mortality from decapitation of upland-type *Ribes* (*cereum*, *roezli*, *viscosissimum*, *cruentum*) to be 30 percent for high-cut and 75 percent for low-cut crowns; for *Ribes* in moist sites (*lacustre*, *bracteosum*, *nevadense*) the mortality of untreated checks was less than 1 percent for high-cut and less than 10 percent for low-cut crowns. Data indicate the importance of soil moisture and ecologic site with respect to the expectancy of kill either with treated or untreated plants. Where the bushes are merely cut off close to the ground and short stubby canes are left, as shown in plate 4,*B*, even dry-site upland ribes such as *cereum* will sprout vigorously unless all stem ends and exposed root-crown tissue are thoroughly covered with the herbicide. Low dosages of 2,4-D and 2,4,5-T will kill cut-off ribes plants if the chemical can be applied directly to the root crown. When the root-crown is wedged deep into a rock crevice or underneath a fallen tree or stump, the cut should be made as low as possible and a generous volume of chemical used to wet all stem ends and provide some run-off down the stems and around the upper part of the root crown. Liquid chemicals, especially those in an oil diluent, will be more effective than dry chemicals on this type of bush.

Salt-borax mixtures, Diesel oil, 2,4-D, and 2,4,5-T can be used effectively in the decapitation work on some or all species of *Ribes*. The big advantage of the 2,4-D or 2,4,5-T over other herbicides is the small quantity needed to kill. About ¼ fluid ounce of 2-percent ester or amine (2,4-D or 2,4,5-T) does about the same job as 2 to 4 ounces of borax-salt or Diesel oil.

BASAL STEM TREATMENT

Application of the growth-regulating substances to the basal part of the stems of intact ribes has been used in greenhouse and small-scale field trials of many of the chemicals listed on pages 6 to 10. Treatments with sodium chlorate, ammonium thiocyanate, ammonium sulfamate, and Diesel oil involved the use of sufficient material to drench the root crown of the ribes coincidental to wetting the basal part of the stems. Aqueous solutions of chlorate, thiocyanate, and sulfamate did no significant damage to any intact ribes plant unless the chemical was absorbed by roots or came in direct contact with exposed cambial tissue or adventitious buds. Apparently the unbroken cortex of ribes is not readily permeable to aqueous solutions. Diesel oil alone or containing an oil-miscible chemical (Offord *16*) caused considerable damage in basal-stem and crown treatments. Nevertheless the volume of oil needed to insure a satisfactory kill was too large for the method to be economical.

In greenhouse tests undertaken in 1946 a low dosage of 2,4-D or 2,4,5-T in an oil diluent was lethal when applied to the basal part of the intact stems. In these tests both the foliage and the soil were protected to prevent contact with the chemical. The plants were killed merely by wetting all principal stems for several inches between the ground line and the lateral or foliage-bearing stems. Although the phytocidal action was most rapid on ribes plants that had foliage



A, Crown of large *Ribes cereum* bush decapitated and treated with a 1:1 mixture of Diesel oil and furnace oil. *B*, Crown of similar untreated bush showing sprouts 3 months after decapitation. *C*, Rock-bound *Ribes cruentum* crown 2 inches in diameter prepared for chemical treatment. *D*, Salt-borax applied to cut-off crown.

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Table 10.—*Effectiveness of 2,4-D and 2,4,5-T liquids applied to decapitated* Ribes *in California, Idaho, and Oregon, 1947–48*

Location and date of treatment	Product	Diluent	Species of *Ribes*	Bushes, cut	Bushes treated	Bushes killed
California:					*Number*	*Percent*
1947–48	Amine of 2,4-D	Water			74	[1] 97
1947	Ester of 2,4-D	Water	*nevadense*		54	[2] 98
1948	Ester of 2,4-D	Oil		Low, high	43	100
1947–48	Amine of 2,4-D	Water	*roezli*		25	100
1947–48	Ester of 2,4-D	Oil			30	100
Idaho:						
Aug. 1, 1947	Ester of 2,4-D	Water		Low	30	90
			lacustre	High	60	51
July 31, 1948	Ester of 2,4,5-T	Oil		Low	10	100
				High	30	100
July 14, 1947	Ester of 2,4-D	Water		Low	104	100
			viscosissimum	High	393	89
July 31, 1948	Ester of 2,4,5-T	Oil		Low	10	100
				High	30	100
			lacustre	Low	10	0
1947–48	No treatment			High	20	0
			viscosissimum	Low	30	84
				High	106	2
Oregon:						
Apr. 20, 1947	Amine of 2,4-D	Water	*cruentum*	Low, high	30	100

[1] 1 surviving high-cut bush treated with 1 percent and 1 with 10 percent of 2,4-D amine.
[2] 1 surviving high-cut bush treated with 10 percent of 2,4-D ester.

buds within the treated area, penetration of the light oil and the phenoxy compound seemed to occur across the unbroken cortex.

The first field tests of the basal-stem treatment were made in 1947 on *cereum*, *nevadense*, and *roezli* in California and Oregon. The ester and amine of 2,4-D in concentrations of 5, 10, and 20 percent of acid equivalent in water or oil were applied with a Hi-Fog gun (see p. 43) fitted with a fine orifice (0.01 and 0.02 inch in diameter) in the nozzle tip. The use of this equipment apparently resulted in a sublethal dosage on the stems of *roezli* and *cereum*, for only about 60 percent of the bushes were killed by the oil formulations and less than 10 percent by the aqueous solutions. Bush kill of *nevadense*, which does not have the regenerative vigor of *roezli* and *cereum*, was 100 percent for plants in the active-growth stage and 80 percent for those in the past-active stage.

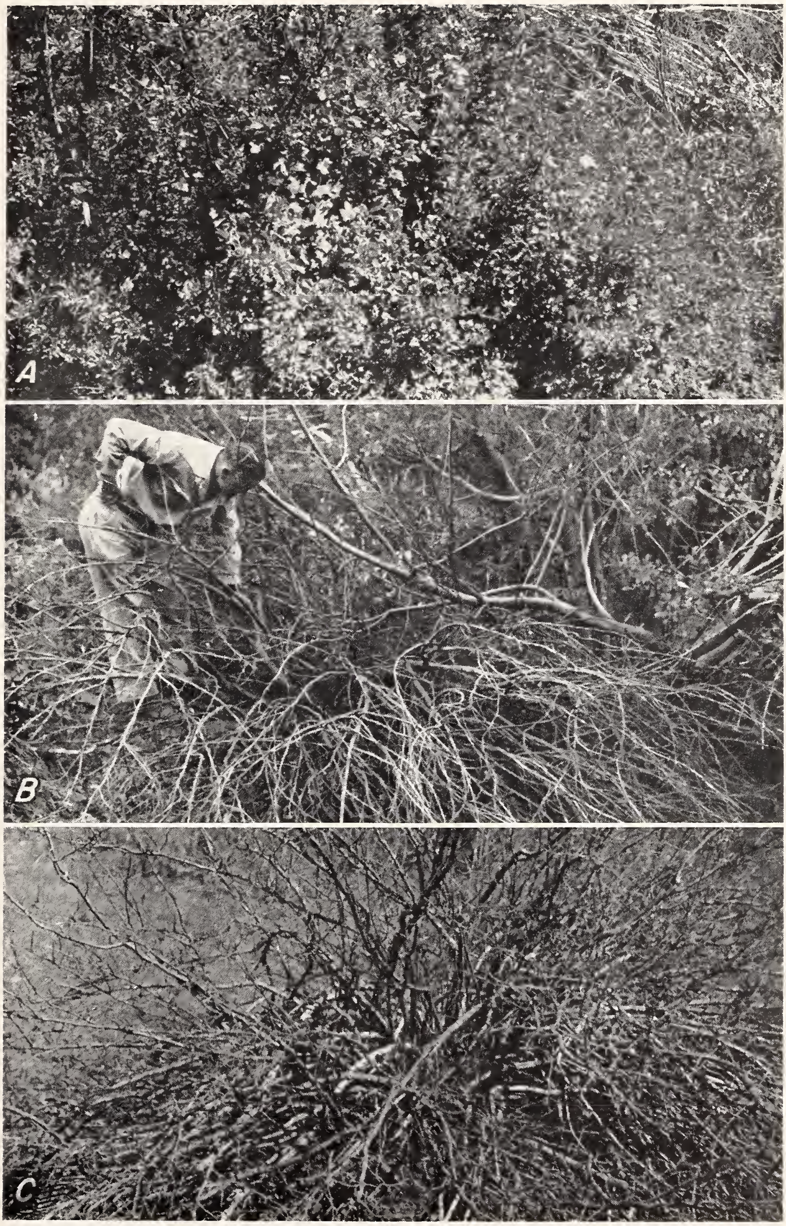
In California during 1948–49 more extensive tests were made on *roezli* and *nevadense* to compare the effectiveness of the ester formulations of 2,4-D, 2,4,5-T, and their mixtures. Several light oils such as Diesel and kerosene were used as the diluent. In these tests all stems directly connected to the root crown were wet to the point of run-off from the ground line to a height of about 12 inches. The run-off was sufficient to wet adventitious buds about the upper part of the root crown. Data collected in tests on 4,314 plants of *roezli* on 100 plots are shown in table 11. Acid equivalent concentrations as prepared in the field varied somewhat from the percentages shown in table 11 because of differences in specific gravity of the several oil diluents and of proprietary 2,4-D and 2,4,5-T materials used.

Results from these tests were clearly superior to those noted for the 1947 treatments, and confirmed the need for thorough coverage and adequate dosage. Although the general trend of bush kill decreased with concentrations of 10, 5, 2.5, and 1 percent of the acid equivalent, an analysis of data for comparable plots showed that the low bush kill was usually associated with a low dosage of herbicide. When the total phenoxy acid was 0.1 ounce or more per bush, a satisfactory bush kill was obtained.

Results of tests on 85 large bushes of *nevadense* from 34 plots were so close to 100-percent bush kill for all stages of plant growth and for all the oil-phenoxy formulations tested that detailed results are not included in table 11.

In basal-stem treatments it is essential to use a light penetrating oil such as Diesel oil, stove oil, weed-killer (aromatic) oil, or kerosene as a diluent. Special weed-killer oils are excellent diluents, but are usually more expensive and more difficult to obtain than Diesel oil. If the ribes has a tough firm bark, an increase in the aromatic content of the oil seems to be an aid in securing satisfactory kill. An effective mixture is one containing 1 part of weed-killer oil to 4 parts of Diesel oil. An oil dark in color serves as a marker in checking improperly treated or missed ribes. If kerosene is used, it should be colored with an oil-soluble pigment. It may also be advantageous to darken the color of Diesel oil. Special weed-killer oils are usually dark enough to mark well.

The use of oil diluent, of necessity, requires the ester form of 2,4-D or 2,4,5-T. Plate 5, *A* and *B*, shows a large *nevadense* bush before and after being treated with the isopropyl ester of 2,4-D in Diesel oil;



A, Large *Ribes nevadense* bush before being treated with 10-percent isopropyl ester of 2,4-D in Diesel oil from a squirt-type oil can; bush spread about 15 feet. *B*, Same bush dead 1 year later. *C*, *Ribes cereum* bush treated with 20-percent isopropyl ester of 2,4-D from Hi-Fog gun. Roots were decaying when picture was taken 1 year later.

TABLE 11.—*Effectiveness of esters of 2,4-D, 2,4,5-T, and mixtures of them in oil for basal-stem treatment of* Ribes roezli *in California, 1948–49*

Chemical	Plant growth	Percent of bushes killed by treatments at indicated acid equivalent concentration				
		20	10	5	2.5	1
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
2,4-D	Commencing	100	100	100		
2,4-D plus 2,4,5-T	Commencing	100	100	75		
2,4,5-T	Commencing	100	100	94		
2,4-D	Active	100	99	100		93
2,4-D plus 2,4,5-T	Active	97	97	92		90
2,4,5-T	Active	99	99	96		98
2,4-D	Past active	81	92	89	84	88
2,4-D plus 2,4,5-T	Past active	96	99	96		84
2,4,5-T	Past active	96	100	95	78	70

application was made with a squirt-type oil can. *C* shows a typical *cereum* 1 year after basal-stem treatment with a Hi-Fog gun.

In contrast to dilute aqueous foliage sprays the effectiveness of oil-ester concentrate, when applied in an adequate dosage as a basal-stem treatment, does not seem to be markedly changed by the seasonal growth stage of the plant. Results of the 1948–49 tests on *roezli* do not clearly favor the mixture of 2,4-D and 2,4,5-T over either chemical alone. However, the vigor of the surviving bushes indicated more residual effect for 2,4,5-T or the mixture of 2,4-D and 2,4,5-T than for 2,4-D alone, especially in the late-season treatments. The choice between the two herbicides should be based on the susceptibility of the species to foliage sprays. There also seems to be some advantage in confining the spray to the stems alone when using the high concentration of herbicide called for by the approved basal-stem treatment. Rapid killing of the foliage seems to be associated with failure of 2,4-D or 2,4,5-T to kill the root crown.

Equipment Used for Applying Herbicides in the Field

The equipment used for applying herbicides in blister rust control work should, as far as possible, fill the following requirements: (1) It should stand up under continuous use and adverse field conditions; (2) should be as light as possible and be designed for use in mountainous areas; (3) should be adequate to perform the desired work at the lowest possible cost, and (4) should be easy to service and maintain in remote areas.

In the Western States the immediate objectives of timber-land management and the character of the terrain, ribes population, and associated vegetation differ so widely that it is not surprising to find several types of equipment and field methods being used in this work. The adaptability of equipment to spraying, decapitation, and basal-

stem treatments and the effectiveness of some of the principal features of the equipment will be summarized in this section.

On cut-over land scheduled for major rehabilitation, such as brush removal by controlled burning or by bulldozer to be followed by planting, broadcast methods of spraying ribes can be used without concern for possible damage to associated plants. Application of these methods eliminates much of the searching time required in finding numerous small ribes plants when hand methods are employed. Although it is a simple task to eradicate these small plants, it is difficult to find them among other vegetation. Costs are high because the ground must be examined piece by piece. Generally one must cover the area two or more times in order to find the small bushes. In broadcast spraying much of the ground cover is killed by the first treatment, and in rework any surviving ribes bushes are more readily seen.

On land with valuable reproduction, pole, or mature trees of desirable species and quality, or desirable forage, it is necessary to destroy ribes selectively without injuring associated crop trees and other useful plants.

Before the type of equipment to be used is designated by the operations leader, broadcast and selective spraying of ribes are further considered on the basis of the number and size of the bushes, the character of the terrain and associated plants, the accessibility of the bushes to roads or motorways, and the availability of water close to them.

Decapitation methods have been most practical in steep and rocky terrain, where workers cannot safely use a grubbing tool or a knapsack sprayer. Along cliffs and on hazardous slopes the crewmen carry pocket-size clippers for cutting off the tops of ribes plants and a small container, such as a 4- to 8-ounce oil can fitted with a screw-on spout, for liquid chemical. Dry chemical is usually packaged in 2-ounce lots in small paper bags, which are carried in a cartridge belt or pocket. On such terrain, ropes, canvas slings, and a special safety device (Winslow *25*) may be used as shown in figure 7.

The basal-stem method of treatment has been most useful on large upright ribes, on scattered populations of such plants, on ribes associated with dense brush, and for extending the effective work season beyond the period when ribes become dormant.

The type of nozzle and discharge rate of the applicator should be chosen for economy, for size and configuration of the stems (i. e., the target), and for speed in wetting the stems. An oil solution containing about 5 percent by weight of the acid of 2,4-D or 2,4,5-T seems to be effective and represents a reasonable compromise with considerations of lethal dosage, adequate volume for the crews to use, and economy in transporting the bulky liquid over rough ground (see fig. 9 and related text).

Thus, depending upon the immediate objective of the eradication job, knapsack and hand sprayers, power sprayers, mist blowers, and oil cans have been used by ground crews for applying the herbicides to ribes, and the helicopter for broadcast spraying of brush and ribes.

Small manually operated dusters and portable power dusters have been used in testing herbicides on ribes, but since their application to field work in blister rust control seems to be limited they will not be described here.

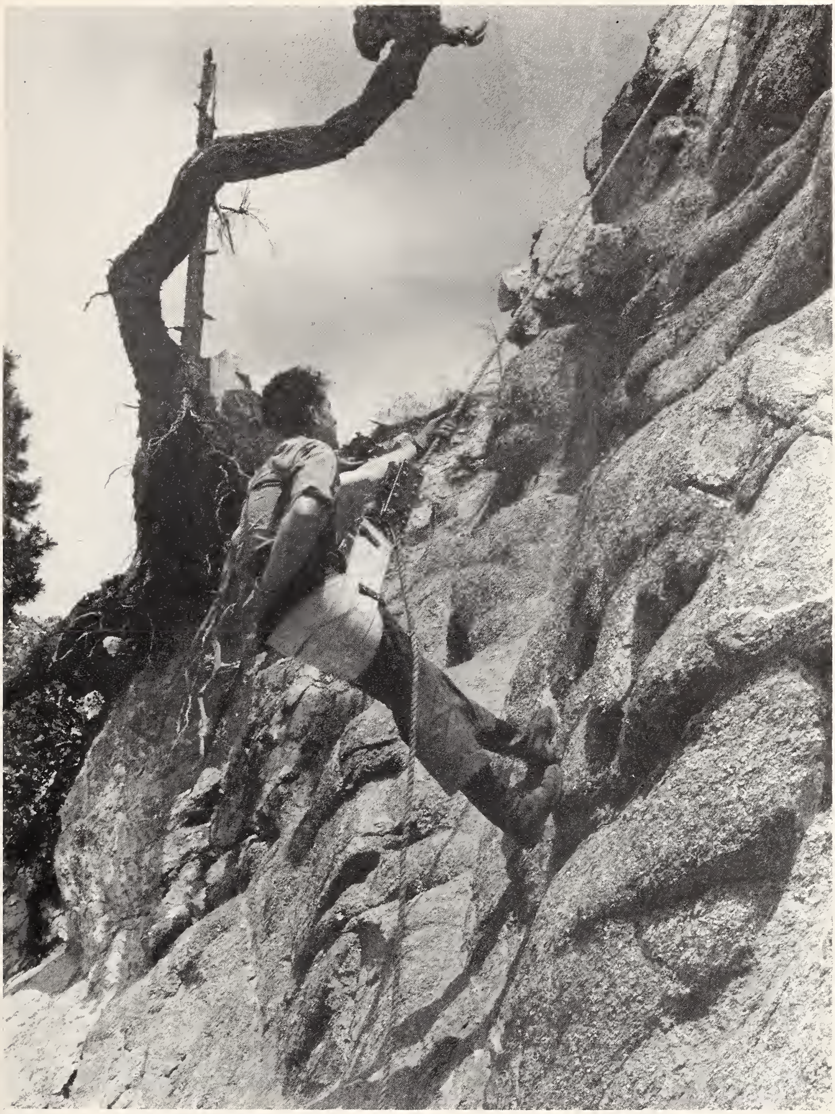


Figure 7.—Rope, canvas safety sling, and a mechanical device for arresting movement along the rope free both hands of worker for ribes eradication.

KNAPSACK AND HAND SPRAYERS

Experience since 1924 has confirmed the general usefulness of lightweight, durable, simply constructed sprayers which can be carried handily on a pack board. A 5-gallon knapsack sprayer equipped with a double-action trombone pump (Offord *et al.*, *19*) has stood the test of many years of work under widely varying conditions in the Western States and is still recommended for the selective spraying of

many types of ribes. The latest model has a 4-gallon tank (fig. 8) to make it a more mobile unit for spraying scattered ribes.

With the use of 2,4-D and 2,4,5-T for ribes eradication, several modifications have been made in accessories for the knapsack-trombone sprayer. A synthetic rubber O-type ring is an improvement over the graphite-cord packing. A scarifier (fig. 8) has been designed for removing ground litter and duff and for scratching the ribes stems as close to the root crown as possible, so that the herbicide will reach all adventitious buds on the basal stems and about the crown. The scarifier is a wedge-shaped 2- by 3-inch piece of flat spring steel fitted with two retaining rings, which are adjustable by means of a wing nut. It slips on and is fastened to a $\frac{3}{8}$-inch iron pipe extension so that the point of the scarifier extends about 1 inch beyond the nozzle. This accessory is especially useful for low-volume spray work and for the basal-stem treatments previously described. The scarifier attachment improves the Hi-Fog gun (see p. 43) for work on many *Ribes* species.

In operations work the scarifier has been used most extensively by National Park Service crews in Yellowstone, Glacier, and Rainier National Parks. In these areas the sprawling multiple roots of *acerifolium*, *laxiflorum*, and *montigenum* necessitate careful application of chemicals. The extra work needed to remove ground litter and locate the root-crown centers with the help of the scarifier has been repaid by consistently good kill.

All sprayers used for applying oil formulations of 2,4-D or 2,4,5-T are fitted with oil-resistant hose and washers. The knapsack-trom-

FIGURE 8.—Knapsack sprayer (4-gallon) equipped with trombone pump (left) and Hi-Fog gun Model D ($3\frac{1}{5}$ quarts, right). Inserts, scarifier fitted to each unit.

bone unit (fig. 9, *A*) fitted with oil-resistant hose, an oil-burner nozzle, and a pump having an O ring hydraulic seal proved to be effective and economical for treating ribes by the basal-stem method. The oil-burner nozzle is a solid-cone type, is held at a 30° angle, and discharges 15 gallons per hour at a pressure of 40 pounds per square inch. The O ring prevents loss of the expensive concentrates and helps the operator to keep hands and clothing free of the oil.

A quart-size hand sprayer in which air pressure is supplied by a carbon-dioxide pellet (fig. 9, *B*) has also been useful for basal-stem treatment of scattered ribes bushes of medium size. For similar treatment of small ribes an oil can with a convenient spout is satisfactory for intermittent use.

A special compressed-air sprayer was used for several years by mop-up crews for the chemical eradication of *petiolare* (fig. 10, *A*) in northern Idaho. This respray work required considerable travel and searching. It was therefore important to provide the men with all accessories needed to keep them working effectively without having to return to a central supply station. One of the obvious requisites was a light-weight and compact spray unit in which the spray solution could be mixed directly.

In figure 10, *B*, the spray man is holding a special sprayer and all equipment and supplies needed for respray work. Special features of this compressed-air sprayer are (1) a 3-gallon galvanized-iron pressure tank with a full-width removable top to facilitate mixing and cleaning; (2) an outlet hose for delivery of spray and a separate air-inlet hose for the air pressure generated by the motorcycle pump; (3) a trigger valve; (4) an extension rod and nozzle clamped to one side of the pump; and (5) a lightweight pack frame for carrying chemical (can), spreader (small bottle), and the can for getting water.

The same sprayer was used for applying oil to young *roezli* in California (pl. 2). At first all members of the crew carried a tank; later the crew leader carried a standard eradication pick and the two other crew men carried spray tanks. The crew leader's duties were to dig or decapitate all large bushes, to lift brush and remove trash and litter that interfered with spraying, and to check the work of the spray men and to dig missed and poorly sprayed bushes.

The major problem in the effective use of oil in upland sites away from roads is the transportation of the oil to the point of use on the work strip. In one of the large oil jobs undertaken in California a 2,200-gallon galvanized-iron tank was used as a storage unit and placed so that it could be filled and emptied by gravity. The oil was drawn from the tank into 50-gallon drums and transported by truck to a roadside filling station close to the job. Five-gallon cans were then used for carrying the oil from the filling station to the work strip. For the knapsack work a standard pack board was fitted with a wooden step on which a 5-gallon can of oil was held in place by a single strap. The complete unit, filled, weighed about 40 pounds. The oil packers spotted the oil cans over the area where they could be reached conveniently by the spray crews. The packers soon learned to judge from the number of bushes how much oil to leave at one place.

A new type of high-pressure back-pack sprayer, called a Hi-Fog gun, was used during the 1947–49 field seasons in Idaho, Oregon, and

FIGURE 9.—*A*, Knapsack-trombone unit (5-gallon) being used to apply oil formulations of 2,4-D and 2,4,5-T to basal stems of dormant *Ribes roezli* bushes, Eldorado National Forest, Calif. *B*, Hand sprayer (1-quart) charged by a carbon dioxide pellet being used for basal-stem treatment under same conditions.

California. This unit (fig. 11) is convenient for applying low volumes of herbicides in aqueous or oil solution at pressures ranging from 300 to 1,000 pounds per square inch. When a fine orifice (0.01 inch

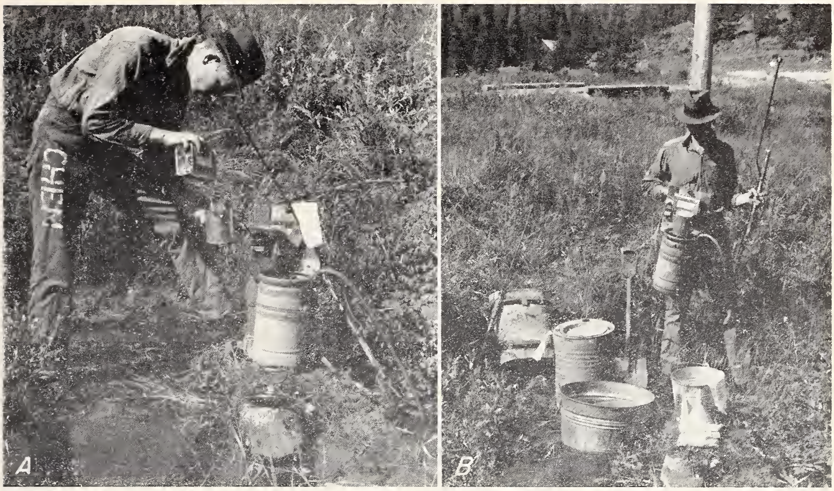


Figure 10.—*A*, Spray man measuring dosage of sodium chlorate needed for 1 to 3 gallons of solution in the compressed-air sprayer. Note the identifying mark (CHEM) for trousers worn in spraying the dangerous chlorate. *B*, Spray man holding equipment needed for respray work on *Ribes petiolare;* on the ground is equipment used for initial spray work on heavy ribes populations.

in diameter) is used in the nozzle tip, the 2,4-D or 2,4,5-T concentrate is delivered as a fine mist or wet fog approximating an aerosol in particle size. The newest Hi-Fog gun (model D) weighs 26 pounds when empty and holds $3\frac{1}{5}$ quarts when filled (fig. 8). The unit takes in the liquid herbicide and simultaneously develops pressure by means of an hydraulic pump built into the head of a short, heavy-

Figure 11.—*A*, Hi-Fog gun Model B ($3\frac{1}{3}$ pints) being used to spray *Ribes lacustre* bushes with 2,4,5-T. *B*, Same unit being used to spray crown sprouts on *roezli* with 2,4-D.

walled cylinder fitted closely with a movable piston. Back of the piston the cylinder carries a sealed-in charge of nitrogen gas at 300 pounds pressure that is retained as a starting pressure when the unit is again recharged.

Tests with the Hi-Fog gun showed that it is especially well adapted to the treatment of crown sprouts in respray work and to the initial spraying of medium to large ribes bushes of scattered distribution, especially those in brush or along streams or rocky terrain where it is troublesome to lay hose lines. The construction of this gun precludes the use of an insoluble marker, such as titanium dioxide, and the small volumes of herbicide employed call for careful work by skillful and dependable operators.

POWER SPRAYERS

In the Pacific coast region truck-mounted power sprayers are being used for the large-scale selective spraying of ribes. Each spray unit consists of (1) a 4×4 Army Personnel Carrier, 1½ tons; (2) a 450-gallon welded-steel tank; (3) a 20-gallon-per-minute plunger-type pump; (4) a 4-cylinder, 4-cycle, air-cooled gas engine with a rating of 25 horsepower at 2,400 revolutions per minute; (5) a portable fire pumper with a maximum output of 60 gallons per minute for transfer and pick up of water; (6) 1,000 feet of ½-inch and 2,000 feet of ⅜-inch mandrel-type synthetic-rubber hose; (7) four orchard-type spray guns and eight rod nozzles (vermorel type on a 3-foot aluminum extension tube with cut-off valve). All hose and nozzle units and connections on the spray truck are equipped with pneumatic-type quick couplings. Each spray or pumper unit is serviced by a tanker truck carrying a 500-gallon tank and a fire-fighter pump for pick up or transfer of water.

For the selective application of dilute aqueous foliage sprays on areas of ribes and brush too small to justify use of large high-volume units, a small slip-on power sprayer mounted on a pickup truck or jeep has been useful. The sprayer unit is a 1-inch, 2-cylinder plunger-type pump powered by a V-belt drive from a 4-cycle air-cooled gas engine, and mounted on a 50-gallon welded-steel tank. The tank is mounted on wooden skids.

These truck-mounted units are favored for applying large volumes of dilute aqueous spray to large numbers of ribes accessible to roads or motorways (fig. 12). Pressures ranging from 50 to 600 pounds per square inch are obtainable, and with the 20-gallon-per-minute pump at least 10 nozzles can be kept operating at one time. Areas 3,000 feet from the pumper can be reached without appreciable pressure drop in the hose lines provided the output at the end of a single long main line is not over 5 gallons per minute. Pressure is regulated at the pump with a spring-loaded regulator. The solution in the tank is mildly agitated with a 3/64-inch jet agitator by using a small part of the discharge volume. Several of the snap-on pneumatic-type couplings equipped with corrosion-resistant springs and oil-resistant washers are obtainable on the market.

The mixing tank can be refilled without shutting off the motor. A quick-acting cut-off valve is closed at the discharge manifold during refilling and mixing; water is transferred either directly from a stream or from the tanker truck. The 450-gallon mixing tank can be refilled

FIGURE 12.—Two members of a crew using a power sprayer to treat *Ribes roezli* bushes with 2,4-D.

in 7 minutes with the fire-fighting type of transfer pump; when refilled the cut-off valve is reopened.

In the Northwest power sprayers have been used widely for applying 2,4,5-T to ribes and brush on cut-over areas. The truck and trailer-mounted sprayers are heavy-duty conventional units acquired by transfer from Federal surplus. Adapting these units to ribes eradication in mountainous terrain has been chiefly a problem of mounting them for transportation over rough logging roads and skid trails. Truck-mounted equipment is satisfactory where roads are passable, while trailer-mounted units towed by a tractor-dozer make additional area accessible.

Two types of nozzles are used in applying dilute aqueous sprays. The adjustable orchard spray gun is most effective on large ribes bushes having dense foliage, or on ribes associated with thick brush. For broadcast spraying in the Northwest an orchard spray gun known as a "pecan" gun has proved to be rapid and effective for wetting the foliage and drenching the root crown of ribes and associated brush. For sparse foliage and small bushes the vermorel or potato nozzle giving a fixed hollow-cone spray from the end of a 3-foot aluminum or iron extension tube provides thorough coverage with an economy of spray material. On seedlings and small bushes with about 5 feet of live stem, a pressure of 100 pounds per square inch or less is adequate. On large bushes with dense masses of foliage, a pressure of 250 pounds per square inch or more is required to drive the spray into the center of the bush. Often a nearly solid stream of spray at high pressure is necessary for wetting the innermost leaves and for treating the root crown.

FIGURE 13.—Roadside spraying of brush and ribes with 2,4,5-T applied broadcast by the turbine blower, St. Joe National Forest, Idaho. Mounted on a turntable the blower can be directed at an angle as the unit moves about 2 miles per hour along the road. *A*, Short-range fishtail nozzle and *B*, long-range round-mouth nozzle in operation. *C*, Typical damage to brush and associated ribes by blower treatment with aqueous solution of 2,4,5-T.

MIST BLOWERS

An axial-flow turbine mist blower has been used effectively for rapid initial spraying of ribes and brush along road-ways. For this work it is mounted on a turntable and carried on a trailer (fig. 13). The blower, powered by a 26-horsepower engine, develops an air velocity of about 150 miles an hour. When the herbicide is introduced into the air stream by an auxiliary pump, a rapidly moving column of finely atomized spray envelops the ribes and brush in its path. By means of a turret-type mounting, a fishtail or round-mouth nozzle can be directed at any angle.

In 1949 aqueous solutions of 2,4,5-T (1 to 4 percent of acid equivalent) were used in a series of tests in which the dosage was controlled by the rate of travel and the number of treatments applied. Two treatments from opposing directions at about 2 miles per hour gave nearly 100 percent kill of *viscosissimum* within 20 feet of the road. These effective results were obtained with 1-percent aqueous solution of 2,4,5-T ester to which 1-percent summer oil emulsion had been added.

High humidity reduces the evaporation loss in the column of finely atomized spray, so that early morning and late afternoon are favorable times for blower work. Wind velocity below 5 miles per hour may be used to good advantage either for increasing the range (working with the wind) or improving turbulence (working against the wind).

On open cutover where ribes bushes are not heavily screened by other vegetation, young *lacustre* and *viscosissimum* have been killed within 30 to 60 feet of the machine. Mature ribes, especially *lacustre*, have been more difficult to kill because the blower was not practicable for delivering a suitable crown drench. Plants highly sensitive to 2,4-D, such as willow, alder, elderberry, wild rose, and *petiolare*, have been killed at distances of 60 to 100 feet.

The importance of roadside work is indicated by survey records showing that 90 percent of the ribes bushes on cutover areas are within 66 feet (1 chain) of logging roads and skid trails. For roadside work the mist blower is manned by two men, one operating the blower and one the vehicle transporting it. Ground is treated at the rate of 3 to 8 acres an hour, depending upon the effective range of the treatment.

A portable (two-man) mist blower weighing about 100 pounds was given a field test in northern Idaho in July 1948. On ribes the effective range of this light-weight blower (120 cubic feet of air per minute, ¼-horse power motor) appeared to be about 12 feet.

HELICOPTER

In 1948 and 1949 a helicopter was used in California and Idaho for spraying ribes with 2,4-D and 2,4,5-T. The objectives were to determine (1) the effects of ground cover, terrain, elevation, and weather on the operating efficiency of the helicopter; and (2) the volume of diluent and weight of herbicide needed to kill ribes in various ecologic sites.

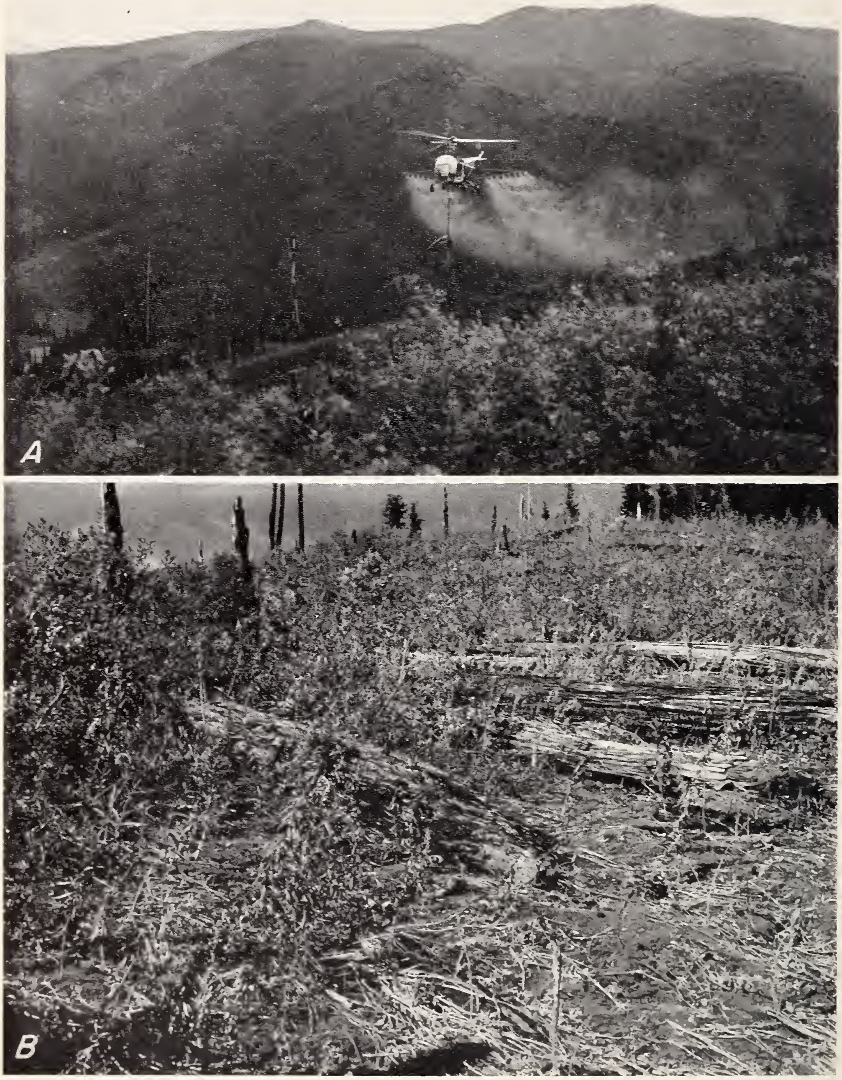
The first sprayings were made on the Sierra National Forest on June 21–25, 1948, where 2,4-D was applied to *roezli* and *nevadense*. A helicopter (178-horse power agricultural model) equipped with a

44-nozzle boom was flown within 30 feet of the ground at elevations of 5,200 to 6,000 feet. The maximum load was 20 gallons. About 38 acres were sprayed with 575 gallons of herbicide at ground speeds of about 30 miles per hour. Eighteen plots ranging from ¾ to 5 acres were treated with various dosages of the following 2,4-D formulations: Isopropyl ester in Diesel oil, aqueous isopropyl ester plus a sticker-spreader, aqueous alkanolamine, aqueous ammonium salt plus summer oil emulsion plus sticker-spreader. The sticker-spreader was used at the rate of 5 ounces, and the light medium summer oil emulsion at the rate of ¾ gallon to 100 gallons of spray. Dosages per acre were from 5 to 30 gallons containing from 3.4 to 53.4 ounces of 2,4-D acid. The percent of bush kill was determined 1 year after treatment by a line transect sample constituting about 10 percent of the area of each of the 18 test plots. Results of these tests are shown in table 12.

TABLE 12.—*Effectiveness of 2,4-D sprays applied with a helicopter to* Ribes roezli *and* nevadense *in California June 21, 25, 1948*

Plot size, acres	Dosage per acre		Concentration of 2,4-D acid in spray	*Ribes* bushes dead August 1949	
	Spray	2,4-D acid		*roezli*	*nevadense*
	Isopropyl ester in Diesel oil				
	Gallons	*Ounces*	*P. p. m.*	*Percent*	*Percent*
2	5	33.4	50,000	86	96
4	10	13.3	10,000	87	68
2	15	20.0		23	45
1½	20	6.7	2,500	94	90
	Isopropyl ester in water plus sticker-spreader				
1	10	6.7	5,000	60	50
4		13.3	10,000	60	50
1	20	13.3	5,000	30	50
2				60	50
¾				----------	10
5	20	26.7	10,000	----------	----------
	Alkanolamine in water				
2	10	3.4	2,500	12	27
3		6.7	5,000	30	----------
1	20	13.3		30	----------
2		26.7	10,000	80	----------
1 [1]		53.4	20,000	84	----------
	Ammonium salt in water plus sticker-spreader plus summer oil emulsion				
1	10	13.3	10,000	10	10
2	20	26.7		41	----------
2	30	40.0		50	29

[1] Spray contained summer oil emulsion and sticker-spreader.



A, Helicopter being used to spray isopropyl ester of 2,4,5-T in Diesel oil on ribes and brush, Coeur d'Alene National Forest, Idaho. *B*, Same area 12 weeks after the spraying; plot margin runs left of center with unsprayed vegetation on left.

Observations 6 weeks after treatment showed that 2,4-D ester in Diesel oil was in general more toxic to ribes and associated brush than the ester or salt diluted with water. Oil solutions apparently settle and wet the vegetation with greater uniformity than do aqueous solutions. Thirteen ounces of 2,4-D acid or more per acre caused significant damage to *roezli* and *nevadense* and other susceptible plants. However, damage to ribes bushes was spotty whenever they were screened by other vegetation. This screening effect was noticeable when the associated brush cover had a density of $\frac{3}{10}$ or more. In general, the apparent kill of ribes and of susceptible brush is correlated closely with the density of spray deposit collected on test plates. Disks of filter paper gave an excellent record of deposits from aqueous solutions dyed red; glass plates were best for recording deposits from oil solutions. Coverage was most uniform on plots where slope and ground obstructions permitted spraying from two opposing directions.

In August 1949, 14 months after the spraying with the helicopter, the bush kill ranged from 10 to 94 percent for *roezli* and from 10 to 96 percent for *nevadense*. The most effective formulation was the ester in Diesel oil; the least effective, the aqueous alkanolamine. On the plot treated with the isopropyl ester of 2,4-D in Diesel oil (33.4 ounces of acid in 5 gallons of oil per acre) 86 percent of the *roezli* and 96 percent of the *nevadense* were dead. The highest kill of *roezli* (94 percent) resulted from the application of only 6.7 ounces of the acid per acre. On this particular plot the helicopter was able to fly close to the brush and to spray alternate strips from the opposite directions. Increased volume of spray compensated for decreased dosage of the 2,4-D. Ribes kill varied greatly on different parts of a single plot where rough terrain, tall trees, or snags had forced the helicopter to change the prescribed flight line and to fly 40 feet or more above the brush.

Ten gallons of oil (or the same volume of water containing 1 to 2 percent of oil emulsion) and 1½ pounds of 2,4-D per acre seemed an effective and practical dosage for the initial spraying operation.

On the Coeur d'Alene National Forest, Idaho, on June 22-25, 1949, a 178-horse power helicopter was used to spray *lacustre*, *viscosissimum*, and associated brush with 2,4,5-T (pl. 6). Dosages of 1, 2, and 3 pounds of 2,4,5-T acid in 5 and 10 gallons of Diesel oil, and in water containing 10 percent of summer oil emulsion were used in treating 12 plots. Elevation of the plots ranged from 4,000 and 4,600 feet. Inspection in September showed that the 2,4,5-T water-oil emulsion formulation appeared to be as effective on ribes and brush as the 2,4,5-T in Diesel oil and was less injurious to conifers.

A final check of the plots was made late in the summer of 1950. The most effective and economical treatment proved to be the 1 pound of 2,4,5-T in 9 gallons of water plus 1 gallon of light medium summer oil emulsion. This treatment gave a 61-percent bush kill of *lacustre* and an 80-percent bush kill of *viscosissimum*. On all plots the 10-gallon dosage was significantly better than the 5-gallon. As might be expected, young ribes plants were killed much more readily than mature bushes. Most of the damage to old bushes was confined to the tops, and the root crowns were still alive. Four of these plots on the Coeur d'Alene National Forest were resprayed in July 1950 with 1 pound of 2,4-D per acre. Two of these respray plots were treated at the rate of 10 gallons of diluent (water plus 1 percent by

volume of summer oil emulsion) per acre and two received 5 gallons. Surviving stem and sprouts from root crowns were heavily damaged by this second spraying.

In May 1950 preliminary tests were made in California with a thermal fogging unit installed in a helicopter for broadcast application of 2,4-D to ribes and white pine. The purpose of these tests was to determine the effects of low dosages of 2,4-D designed to cause a systemic defoliation of ribes without damaging the pine. In treatments made at Pescadero the butoxyethanol ester of 2,4-D was applied at calculated dosages of 3, 6, 9, and 12 ounces of acid equivalent per acre to potted white pine placed in the open and to ribes placed in the open and under brush providing light, medium, and heavy shade. The 6-ounce dosage caused nearly complete defoliation of ribes in all types of brush cover and did not damage the pines.

Experience in Idaho and California with all spraying and fogging by helicopter clearly shows the importance of spraying alternate strips from opposing directions and allowing at least a 10-percent overlap.

Crew Methods Used in Spraying Ribes

SELECTIVE SPRAYING IN CALIFORNIA

The size and organization of crews engaged in the selective spraying of ribes in California are governed by the type of equipment available and the method of treatment required. For the large power sprayers used for applying aqueous solutions, the size of the crew must be related to the pump capacity of the sprayer. With a 20-gallon-per-minute pump and a pressure range up to 600 pounds per square inch, a 10-man crew is most effective. Such a crew should be organized as follows: One spray foreman in general charge of the crew and responsible for the planning, operation, and maintenance of the crew and the equipment; 1 spray man responsible to the foreman for operation and maintenance of the equipment and a continuous supply of spray material to the nozzles; and 8 nozzle men responsible to the foreman for hose, fittings, and nozzles, and for the proper spraying of ribes.

With a small power sprayer (4- to 5-gallon-per-minute pump) two injector-type nozzles can be operated successfully. In selective spraying, two nozzle men would apply 450 to 600 gallons per 8-hour day, depending on topography, density of brush, and the ribes population.

Before spraying is begun, a work plan is prepared from preliminary survey data and from on-the-ground inspections by the supervisor. For large-scale operations such a plan includes not only the method of working and the equipment to be utilized, but also such details as dividing the area into suitable work blocks, prestringing of block boundaries and work lanes, order of work, size of crew, location of water supplies, hose lay-outs where power sprayers are to be used, strategic locations for stationing the pumping units, and the proposed order of moves.

Patches of ribes plants that do not extend more than 500 feet from a road can best be reached with 3/8-inch lateral hoses, connected directly to the sprayer or from main-line take-offs and laid parallel to the road or direction of travel of the spray truck. To reach ribes occurring 500 to 2,000 feet from the road, 1/2-inch main-line supply

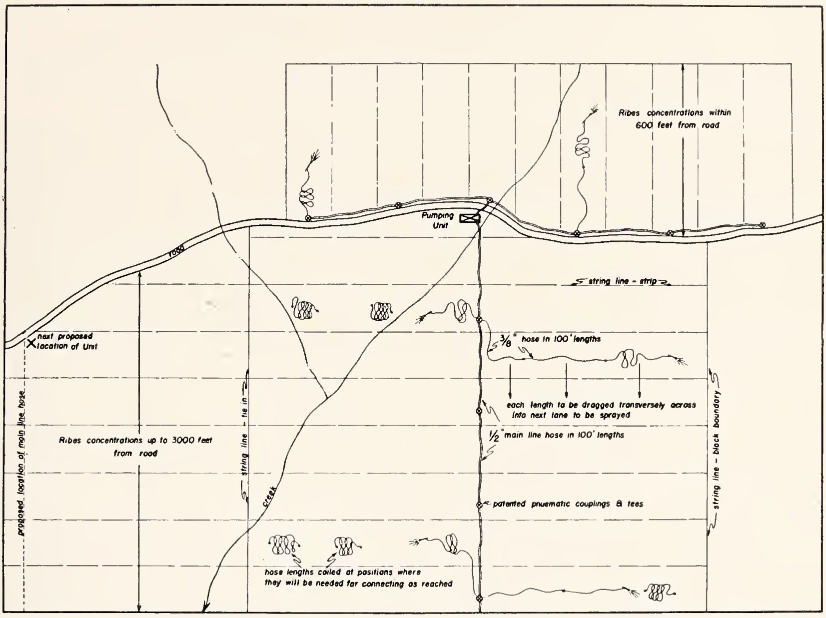


FIGURE 14.—Hose arrangement used with power sprayers in chemical eradication of ribes. Pacific Coast Region.

hoses should be laid at right angles to the road. On level or gently sloping work blocks about 3,000 feet of ½-inch main-line hose has been used. With long main lines the ⅜-inch lateral hoses should be laid for 500-foot strips at right angles and on both sides of the established main line. For this situation it is important that the main lines be located more or less centrally through a work block, or 1,000-foot wide subdivisions of a work block, where large numbers of ribes bushes extend for more than 1,000 feet. To the extent that road locations and ribes distribution permit, the hose lay-out is planned so that spray men work down hill or along the contour.

Where power sprayers are used for treating foliage with aqueous solutions, water supplies can be a controlling factor on the number of possible pump-unit locations. It is preferable, from the standpoint of continuous operation, to locate the pumpers at the source of water supply, or, failing that, to provide tank trucks to carry the water to the location of the sprayer.

Each nozzle man is assigned to work a number of contiguous strips within a block. As shown in figure 14, work blocks are delimited by string line, and further divided into prestrung narrow lanes, the direction of which would be at right angles to the main-line hoses laid out from the pumping unit. Several contiguous strips are assigned to one nozzle man so that the lateral hose can be moved progressively between adjacent strips, thus minimizing the time lost in moving hose. A nozzle man works alone in his individual lane, starting each lane at the main line, connecting his lateral hose from suitable tees and fittings on the main line, and working to the end of his strip, which is marked by a transverse string. After spraying out about 500 feet from the main line, the individual lengths of lateral

hose are moved over one at a time into the next work lane. Detached lengths of hose are made into loose figure-eight coils in the center of the new lane and are left in a convenient spot where nozzle men can connect to them quickly as they work out once again from the main line.

An experienced nozzle man will spray effectively with about 500 feet of $\frac{3}{8}$-inch lateral hose in 100-foot lengths without becoming overburdened with the task of handling and moving the hose. Main lines are connected in 100-foot lengths to allow the insertion of suitable tees and fittings for connecting lateral hoses. As work lanes are completed, the tees are moved up or down the main line for convenient take-off points. Many of the factors just discussed are illustrated in figure 14. Work plans must be modified to fit the special conditions encountered in the field.

BROADCAST SPRAYING IN IDAHO

The field organization and crew methods employed for broadcast spray work in Idaho vary with accessibility and topography of an area, and differ in some respects from the methods used in California for selective spraying. In broadcast spraying all ribes and brush are treated uniformly at the specified dosage rate. Rocks, stumps, and obviously bare ground are not sprayed, but no attempt is made to search for and treat ribes as is done in selective spraying. Broadcast spraying uses more chemical and diluent per acre than does selective spraying, but labor charges per acre can be less than for selective work. When searching and selective spraying have resulted in the use of about 60 gallons of spray and 2 man-days of labor per acre, broadcast spraying has used as much as 800 gallons per acre with only $\frac{3}{4}$ man-day for labor. Methods tests made on the Clearwater National Forest in 1950 have shown that brush and ribes on terrain typical of western white pine area can be sprayed broadcast for about $\frac{3}{4}$ man-day by power sprayer with the pecan-type orchard gun.

An area that can be reached with the turbine blower is mapped for advance treatment, which generally precedes by one season the working of the adjacent or intermingled ground by other methods. Otherwise the procedures for mapping the spray area and for planning the operations work are essentially the same as described for Selective Spraying in California.

Main-line hose of $\frac{1}{2}$-, $\frac{7}{16}$-, and $\frac{3}{8}$-inch diameter in 100-foot sections have been used for supplying solution to the mapped area. Six hundred feet has been used most frequently in Idaho as the effective distance between main lines. Much arduous work in laying and retrieving the main-line hose can be avoided by proper original placement in relation to subsequent moves and to its anticipated location when the job is completed. The following practices will prevent wasted effort in handling and laying hose: (1) Place the initial line near the top of the area to be sprayed; (2) pack the hose to or from an area on level or down grade whenever possible; (3) place the main line along contours or on ridges and keep it above the area to be sprayed; and (4) begin the spraying at the distal end of the main line to relieve sections of hose for retrievement or for movement down hill to the next location. The time required to lay $\frac{1}{2}$ mile of main-line hose on contour in steep area with medium brush density is about 5 man-hours. This amounts to 10 man-minutes per acre for

the 30 acres that can be treated below this section of main line. Level terrain can be sprayed on both sides of the main line, thus cutting in half the cost of laying the main line.

Each nozzle man is equipped with one 150- or 300-foot section of ⅜- or ¼-inch pressure hose and a pneumatic tee which permits him to plug into similar pneumatic couplings at each 100-foot section in the main line. Two 50-foot strips are worked on the downhill side from each connection. The lateral hose is placed in a figure eight at the top of the strip and is pulled out as the strip is sprayed. At the end of the strip the nozzle is detached and the worker returns to the main line, laying a string line to mark the boundary of his next strip as he goes. The lateral hose is easily pulled in and dropped at the head of the next strip. When a strip is longer than one lateral, sections are added at the terminal of each lateral to reach the entire length of the strip. Each section is handled in the same manner as the first and when it is pulled up, the coil is moved across to the adjoining strip in the same relative position.

Summary of Chemical Methods of Ribes Eradication

In the Western States from 1928 through 1949 about 30,000 acres of forest land supporting heavy populations of ribes were sprayed once with one of the following herbicides: Sodium chlorate, ammonium sulfamate, Diesel oil, 2,4-D, or 2,4,5-T. About 24,000 of these acres contained *petiolare*, which was destroyed by spraying chiefly with aqueous solutions of sodium chlorate. Most of the rework (second or third spraying) was done on *petiolare;* during this period about 10,000 acres were sprayed twice and 5,000 acres three times to eliminate missed bushes and those established in the area from seed. About 600 tons of sodium chlorate were used.

From 1944 through 1947 about 10 tons of ammonium sulfamate were used with success in northern Idaho for killing *lacustre*, *inerme*, and *petiolare*. Straight Diesel oil was used for ribes eradication work in California from 1937 through 1941, but was discontinued early in the war years (1942) because of restrictions on petroleum products. By 1946, 2,4-D had replaced Diesel oil as the herbicide for all spray work in California. Diesel oil is now used as a diluent for 2,4-D and 2,4,5-T in most of the decapitation and basal-stem work.

From 1946 through 1949 the ribes plants on 7,897 acres, chiefly in Idaho and California, were sprayed for the first time with dilute aqueous solutions of 2,4-D and 2,4,5-T applied with a power or knapsack-trombone sprayer or as concentrates with a knapsack high-pressure unit. A summary of this practical control work is given in table 13. An estimated 7,947,000 ribes plants were sprayed with 1,046,620 gallons of dilute sprays, an average of 17 fluid ounces per bush, and 732,200 ribes with 15,940 gallons of concentrated sprays, an average of 2.8 ounces per bush.

Ribes killed in spray work with 2,4-D and 2,4,5-T ranged from 50 to 99 percent, depending on the species, age, and ecologic type of plant, and on the efficiency of the crew. In all cases, however, the initial chemical treatment opened up the area, so that the subsequent working was easy either by spraying or by grubbing.

Although the acreage sprayed was just about 1 percent of the total worked by all methods, the importance of chemical methods is much

TABLE 13.—*Summary of* Ribes *eradication with 2,4-D and 2,4,5-T sprays in the Western States, 1946–49*

Location, equipment used, and year of work	Type of herbicide	Concentration of acid equivalent	Area sprayed	Time worked [1]	Quantity of spray [2]
California:					
Power sprayers:		*P. p. m.*	*Acres*	*Man-days*	*Gallons*
1946	Ester, salts of 2,4-D	360–1, 440	328	220	40, 950
1947		500–1, 000	1, 554	1, 455	360, 020
1948	Salts of 2,4-D	500–750	1, 242	2, 311	330, 210
1949		500–750	1, 058	1, 940	234, 510
Total			4, 182	5, 926	965, 690
California, Oregon:					
Knapsack—high-pressure:					
1948	Ester of 2,4-D in Diesel oil	20, 000	13	26	20
1949	Ester of 2,4-D in kerosene	10, 000	26	37	60
Total			39	63	80

Idaho, Montana, Washington, Wyoming:					
Power sprayers:					
1948	Ester of 2,4,5,-T	2, 000–3, 000	551	544	12, 750
1949			849	866	46, 780
Total			1, 400	1, 410	59, 530
Knapsack, high pressure:					
1948	Ester of 2,4,5-T	20,000–40,000	650	872	10, 210
1949			565	1, 287	5, 650
Total			1, 215	2, 159	15, 860
Knapsack, trombone:					
1948	Ester of 2,4,5-T	2, 000–3, 000	357	387	4, 450
1949			704	1, 598	16, 950
Total			1, 061	1, 985	21, 400
Grand total			7, 897	11, 543	1, 062, 560

[1] Includes time of foreman, tanker and sprayer operator, and all nozzle men.
[2] Rounded to nearest ten.

greater than this percentage indicates. For example: in California, of 111,186 acres worked by all methods in 1948 only 1,242 acres were sprayed. Nevertheless, at an expenditure of only 3.4 percent of the total man-days, an estimated 3 million ribes plants were sprayed, which was 29 percent of the year's total for all methods of eradication.

Chemical methods used in control work have several advantages over grubbing. For some species, such as *petiolare*, these methods represent the only feasible means whereby the species can be destroyed; for others, such as *roezli*, they constitute significant labor savings; and for many species they should reduce the number of viable seeds stored in the soil, because many chemicals, especially 2,4-D and 2,4,5-T, kill ribes seed. For all spray work done from 1928 through 1949 in the far West, it is estimated that about 136,000 man-days were saved. Many of the areas that were sprayed represented the choicest white pine sites but they would not have been worked by hand methods because of the heavy costs.

Since 1935 the treatment of decapitated ribes bushes with dry or liquid chemical has been a proved and accepted practice in the Western States. Several tons of dry salt-borax, ammonium thiocyanate, and ammonium sulfamate have been applied to troublesome root crowns. Liquids similarly used have included Diesel oil, aqueous solutions of sulfamates, and aqueous solutions and oil concentrates of 2,4-D and 2,4,5-T. Because the decapitation method has been used intermittently by crews as a supplement to grubbing work, it has not been feasible to check closely on the results. Thus data are not available from operations work on the number of bushes treated, the percent of bush kill, and the time saved by the decapitation method. On the basis of accumulated averages of test plots the kill has probably exceeded 97 percent.

Basal-stem methods were used on a large-scale basis for the first time in 1949, when *Ribes cereum* (389 acres on Shasta National Forest) and *roezli* (5 acres on Eldorado National Forest) were treated in a series of tests with 2,4-D and 2,4,5-T concentrations ranging from 10,000 to 200,000 p. p. m. of acid equivalent in oil diluent. More than 90 percent of the bushes were killed with solutions containing 50,000 p. p. m. or more of the acid.

Recommendations for the Use of 2,4-D and 2,4,5-T in Control Work

Recommendations summarized in table 14 are considered to be the basic ones for spraying, decapitation, and basal-stem treatments with 2,4-D and 2,4,5-T of ribes of principal importance in control work in the Western States. If several species of *Ribes* are intermingled, 2,4,5-T is usually used because it is effective against all *Ribes* species.

Specific instructions on all phases of chemical work are revised annually and compiled into a manual for field work. In these manuals basic recommendations are modified to meet local needs, which are too diverse to be discussed in this circular.

Sensitivity to dilute aqueous sprays is the criterion used for recommending 2,4,-D or 2,4,5-T for any particular *Ribes* species. For high-volume spraying with conventional equipment, apply during the active growing season any salt or ester of 2,4-D or ester of 2,4,5-T as a dilute aqueous spray. For low-volume spraying with high-pressure

equipment, use the amine or ester of 2,4-D or the ester of 2,4,5-T in oil or water. Apply at any time between full leaf development in the spring and beginning of leaf drop late in the summer. However, the oil diluent is favored either for early or late season work; otherwise concentrated aqueous sprays containing 1 to 2 gallons of summer oil for each 100 gallons are used.

To conform to recently adopted procedures of State weed control conferences, concentrations in table 14 are expressed as pounds of acid per 100 gallons of spray. Concentrations previously expressed as parts per million or percent in this circular may be compared with pounds per 100 gallons of water as follows: 1,000 p. p. m.=0.1 percent=0.833 pound avoirdupois.

When sprayers equipped with agitators are used, for each 100 gallons of spray 1½ pounds of mixed titanium dioxide and barium sulfate pigment (Titanox B–30 or equivalent) or 1 gallon of summer oil emulsion is added as a marker. Summer oil also serves as a spreader and may be used in sprayers not equipped with an agitator. However, summer oil and an insoluble marker such as Titanox should not be combined, because they form sticky curds that clog spray equipment.

A follow-up spraying to kill sprouting or missed bushes is preferably undertaken the second season after the initial treatment. The principal reasons for this practice are the tendency for many of the live crowns to delay resprouting until late in the season of the year after the initial spray work and because some of the crown sprouts that may persist throughout the first growing season subsequently die back.

The age of ribes plants, the character of the soil, and the vegetative associates of the ribes all have a bearing on the ease with which the ribes can be treated and killed with 2,4-D. Any of these factors that reduces the moisture available to ribes, or modifies the soil temperature so as to hasten seasonal development, will shorten the period of high susceptibility to 2,4-D. Thus when practical spray work is being scheduled, plants on south and southwest slopes, especially on shallow and rocky soils, should be sprayed earlier in the season than those on deep, moist soils in flat sites or on north and northeast slopes. In dense brush, ribes grows more slowly and becomes resistant to 2,4-D earlier than it does in open sites where there is little or no competition from deep-rooted vegetation.

The basal-stem treatment is applicable only to erect or semierect ribes with principal stems and root centers that may be recognized easily. The use of oil as a diluent is essential to the success of this treatment. Of the species of *Ribes* responding to the treatment (note 10 *Ribes* species in table 14), 41.7 pounds of 2,4,5-T acid in 100 gallons of oil diluent is recommended for 6 species and 2,4-D for the others. Only a light penetrating oil (Diesel or weed-killer oil) should be used with the ester of 2,4-D or 2,4,5-T any time of the year when it is practical to work. Lower and higher concentrations of the chemical have been used with success in operations work, but the recommended concentration offers a practical compromise on the volume and dosage needed by seasonal workers to get thorough coverage and satisfactory kill.

The success of decapitation work depends more on a low cut and on a thorough coverage of all cut surfaces than on the type and concentration of toxicant. For upland ribes a mixture of equal parts

of common salt (fine crystal) and powdered borax is cheaper, less hazardous, and just as effective as borax-chlorate. Ammonium sulfamate is effective on decapitated crowns, and is often used instead of the salt-borax mixture for treating mixed populations of *petiolare*, *inerme*, and *lacustre*. Liquids used in decapitation work include Diesel oil, saturated aqueous ammonium sulfamate, and concentrates of 2,4-D and 2,4,5-T amines and esters in oil or water. For early or late-season treatments when rains are common, ester compounds should be used in Diesel or other light oil as a diluent. At concentrations of 16.7 to 41.7 pounds of the acid per 100 gallons of oil or water 2,4-D and 2,4,5-T are preferred herbicides for decapitation work, though others may be used when they happen to be readily available.

For certain *Ribes* species varietal differences in sensitivity to 2,4-D have been noted, and recommendations may differ from those given in table 14. For example, a varietal form of *roezli* that occurs in the northern part of the Sierra Nevada can be more readily killed with a mixture of 2,4-D (0.42 pound) and 2,4,5-T (0.83 pound) than

TABLE 14.—*Concentration and type of treatment recommended for use of 2,4,5-T in control work on* Ribes

Ribes species	Pounds of acid per 100 gallons of diluent			
	Spraying		Decapitation	Basal stem
	High volume	Low volume		
acerifolium	2.1	16.7	41.7	----------
binominatum	2.1	----------	----------	----------
bracteosum [1]	.83	16.7	16.7	41.7
cereum [2]	2.5	16.7	41.7	41.7
coloradense	1.7	16.7	16.7	----------
cruentum	1.7	----------	16.7	41.7
erythrocarpum	1.7	----------	----------	----------
inerme	2.5	----------	41.7	----------
irriguum	2.5	----------	41.7	----------
klamathense	2.5	----------	41.7	----------
lacustre	1.7	16.7	41.7	----------
lasianthum	2.5	----------	41.7	----------
laxiflorum	1.7	----------	41.7	----------
lobbi	1.7	16.7	16.7	41.7
marshalli	2.5	----------	----------	----------
montigenum	2.5	16.7	41.7	----------
nevadense [3]	.83	16.7	16.7	41.7
petiolare [2]	.42	16.7	16.7	----------
roezli [1]	.83	16.7	16.7	41.7
sanguineum	2.1	16.7	16.7	41.7
setosum	1.7	16.7	41.7	41.7
triste	2.5	----------	----------	----------
tularense	2.5	----------	----------	----------
viscosissimum	2.1	16.7	41.7	41.7
watsonianum	2.5	16.7	41.7	41.7

[1] Preferred treatment is with 2,4-D at 0.42 pound for high-volume spray; concentrations for other treatments are the same.
[2] Or 2,4-D.
[3] 2,4-D only.

with the 2,4-D (0.42 pound) alone. *Ribes lacustre* in Oregon has been harder to kill than the same species in northern Idaho, seeming to require at least 2.1 pounds of 2,4,5-T in sprays applied in generous volume. In Idaho high-volume sprays of 2,4,5-T at a concentration of 0.83 pound per 100 gallons have been effective on this species early in the growing season, though most of the practical work was done with the 1.7-pound spray. The principal reasons for differences in the sensitivity of any one *Ribes* species to 2,4-D or 2,4,5-T have been discussed previously in the section, Chlorinated Phenoxy Compounds.

MECHANICAL METHODS OF RIBES ERADICATION

The following special power and hand tools have been designed and used by blister rust control workers to aid in ribes eradication work: (1) A dual-purpose power unit (crawler tractor) equipped with a front-end brush rake and a rear-end winch operating a ribes grapple or hook, (2) a claw mattock designed for regular grubbing work for all types of ribes, and (3) a ribes peavey for uprooting large *roezli* and *nevadense.* The tractor unit was used in operations work in California from 1939 through 1944, when it was displaced by the more economical chemical methods. The ribes peavey was used in methods tests from 1938 through 1941 and to a limited extent by regular eradication crews working on large ribes along roads and abandoned logging railroad rights-of-way. The claw mattock has proved to be so much more effective than the standard pick mattock that since 1941 it has become a standard tool for crew use in the Western States. The equipment and methods described should be applicable to other projects requiring the eradication of woody plants.

Crawler Tractor Work

The success already attained with the crawler type of tractor for the permanent suppression of ribes and brush in stream-bottom areas indicated that a smaller and more mobile form of this machine (Offord *et al., 19*) could be used in the eradication of heavy growths of upland ribes. As a result of preliminary tests made on the Plumas National Forest from May 30 to June 2, 1939, plans were formed to assemble a dual-purpose power unit which could be used in upland sites for directly uprooting ribes by means of a brush rake and for pulling them out with the aid of a special hook.

The power unit as purchased consisted of a caterpillar-type tractor (25 horsepower on the draw bar), a hydraulic lift for the front-end brush rake, and a single-drum logging winch for mounting on the rear end of the tractor. The necessary power take-off for the front-end lift and for the rear-end winch were installed by the manufacturers.

Field trials of the assembled unit were begun near Shaver Lake on September 15, 1939, and after October 16 were continued for another month at Soquel CCC camp, both in the Sierra National Forest. For machine work only exceptionally heavy patches of ribes were selected, from 3,000 to 6,000 bushes per acre primarily of *roezli.* About 40 acres were cleared of ribes during the course of these methods tests.

FRONT-END BRUSH RAKE

In designing the rake shown in plate 7,*A*, careful consideration was given to its weight in relation to that of the tractor, and especially to a scheme for mounting the rake. In the final design, the rake sits close to the radiator of the tractor, thus effectively minimizing the nose-heavy action of the usual bulldozer unit.

The method of using the front-end rake is to scoop out the ribes bush with a minimum of soil disturbance and to avoid, as much as possible, moving dirt along with the uprooted bushes. Briefly, the operating technique is to advance toward the bush with the tractor in low gear and the hoist in high gear. The rake is lowered so that the cross member near the ends of the rake teeth will engage the bush just below the crown, usually from 3 to 5 inches beneath the ground surface. As the machine moves forward and uproots the bush, the rake is raised slowly to clear the roots of clinging soil. When large clumps are uprooted, it is usually necessary to back up the machine after the uprooting operation is completed. With single bushes or small clumps the forward motion is continued and the next bush is uprooted, the previous one being allowed to fall away from the rake or become entangled with the next one. The machine has a slight nose-heavy action when the rake is being used, so that the operator must allow for a sharp increase in the angle of digging. This action becomes important when a large clump is being dug, and is counteracted by lifting the hoist slightly in advance of the hard part of the pull.

Under special conditions it may be difficult to maneuver the machine and root out the ribes without destroying some coniferous reproduction. Small conifers and *roezli* sometimes grow with their roots intermingled. In such cases the rear-end hook may be employed more selectively; hand work may be needed to avoid destroying or damaging the small trees.

The machine works best on level ground, but is effective either along a contour or up and down hill. Ribes could be rooted out of small patches of brush, although it was found that the 25-horsepower unit did not have enough weight and power to make it useful as a brush-stripper under all types of ground and brush conditions. The rake is especially helpful for rolling logs and uprooting ribes growing around rotten stumps; such operations normally require an excessive amount of hand work. This tractor unit has also been used for cutting man-ways through low brush on comparatively flat ground as a preparatory treatment for the grubbing work of regular crews (pl. 7, *F*).

RIBES HOOKS FROM THE WINCH

The ribes hook (pl. 7, *B*, *C*) adequately resolved the following requirements: Durability, practical weight for the operator, steady pulling (i. e., correct ratio between length of the side arms and draught of the digging teeth), and correctness of design for doing clean eradication work.

The hooks used in 1939 weighed about 40 pounds and had five teeth welded to the frame (fig. 15). For work in rocky soils undertaken in 1940 a hook was made having six replaceable teeth. A 6-foot bridle of ¼-inch steel cable was attached to the two arms of the hook. The lead end of the bridle was then attached by means of a hook or small

A, Ribes hooks, snatch block, and cables hung on bulldozer rake ready to be moved to new location. *B*, Six-tooth ribes hook, 1940 model. *C*, Five-tooth ribes hook in use on *Ribes roezli*. *D*, Short cable means least time lag between hookman's signal and taking up on slack in cable line. *E*, Rake in use on large *roezli*. *F*, Brush can be broken off at ground level by the rake, leaving an accessible route through the dense brush for eradication crews.

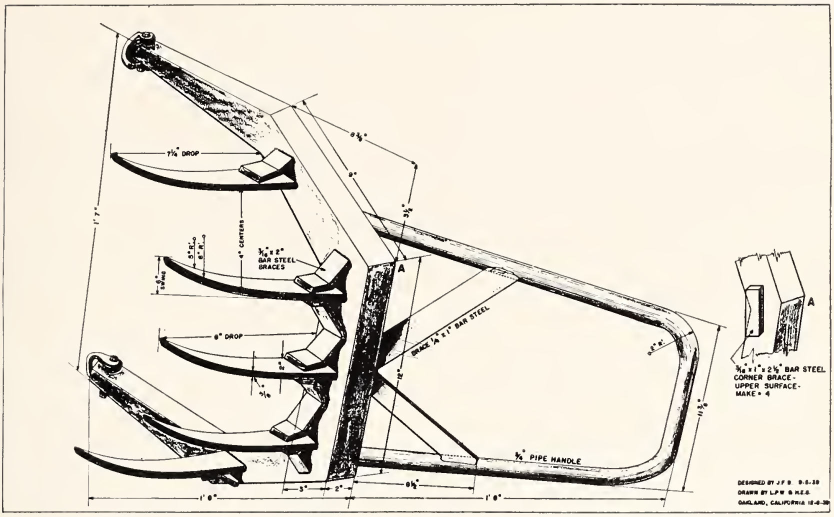


FIGURE 15.—Five-tooth ribes hook for power eradication of *Ribes roezli.*

clevis to the end of the main cable from the winch. A snatch block or sheave was hung on a convenient tree and the tractor was spotted from 20 to 30 feet from the tree so as to allow the line to spool properly on the drum while running through the sheave. The sheave makes it possible to work an area of ground roughly equivalent to a half circle without having to swing the rear end of the tractor.

The hook was set behind the crown of the ribes bush, and enough of the operator's weight was applied to insure setting the teeth of the hook firmly into the ground. At a signal from the hook tender (pl. 7, *D*) the main cable was spooled in just enough to break the ribes roots clear of the ground. The ribes bush was pulled out cleanly, the roots breaking off well down in the ground, as shown in plate 7, *C*. Two men worked together with the hook, one handling the hook and the other freeing and tossing aside the pulled bushes, helping to haul back the line for another pull and giving signals to the operator of the tractor. Whenever practical, work should be done so that the pull is up hill, because a more effective grab can be made on the ribes and it is easier for the hook-man to carry or drag the hook down hill to the next bush. It is more economical to move the tractor and to keep the main-line cable short than to work the hook at extreme distances, because (1) the tractor operator must have a clear view of the work, (2) on short pulls there is less slack in the cable to be taken up after each ribes has been eradicated, and (3) a long main line (200 feet or more) adds significantly to the manual work necessary to keep the line taut and free of obstructions.

Care must be taken when working around trees or rock to see that the hook does not catch on solidly anchored material. Some hooks were broken while ribes were being pulled from under trees and away from large rocks.

Two hooks were attached to the main line, and the crew work was organized so as to keep the two pulling together. Comparative tests, however, showed that more work could be done with a single hook,

largely because of the patchy distribution of ribes. Unless the cables on both hooks were kept tight and at equal distances from the main line, too much slack had to be taken up in the cable each time a pull was made. After a ribes bush had been pulled, the hook was carried or dragged a short distance before it was set in working position on the next ribes bush. Thus the main cable was spooled off the drum by manual labor, and to facilitate this aspect of the work, tension on the drum was kept at a minimum. The rather loosely wound cable was thus subjected to more than the usual amount of wear.

To a limited extent the hook can be used to pull ribes in brush, and to move small logs and poles. However, when larger logs and stumps need moving, the ribes hook should be replaced by a heavy single-pointed steel hook or light logging choker.

COMPARATIVE EFFECTIVENESS OF THE RAKE AND HOOK

The front-end rake is most effective where ribes bushes are present in large numbers and where coniferous reproduction is scattered or absent. The rake disturbs the soil more than does the hook, but it will normally be a cheaper and faster method except on steep or rocky slopes. The regeneration of ribes from soil-stored seed is governed largely by the amount of ground disturbance associated with the eradication of the parent bush. This point is kept in mind in deciding on the extent to which the rake is to be used. The rear-end hooks may be employed under all conditions, but most advantageously where the ribes bushes are more or less clearly defined as separate bushes, and where there is not too much debris to be moved. The hook is not so useful as the front-end rake for removing ribes concealed and protected by a clump of brush, or by partially decayed logging debris.

Although it is advantageous to have the crawler tractor furnished with the front-end rake, any tractor that carries a rear-end winch can be fitted with the necessary cable and ribes hooks.

COSTS OF CONSTRUCTION AND OPERATION

The following cost data (1939–40 prices) relating to the rake, hook, and accessories will serve as a guide to the amount of material and labor needed to supply them. The steel for the ribes rake cost $219 and the labor to assemble and weld it amounted to $112. The two ribes hooks used from the rear-end winch and the necessary cable and clevises cost $32 each. Each hook required about 6 hours of a welder's time to assemble it. The cost and type of accessories needed to operate the special ribes hooks from the rear-end winch were a 6-inch steel snatch block ($7), 50 feet of ¼-inch steel cable ($4), a choker hook and ferrule ($8), and about 400 feet of ½-inch steel cable ($30).

Cost data on the operation of the machine recorded from September 16 to October 18, 1939, in the course of methods tests permit the following conclusions:

With a ground crew of two or three men using the hooks, the total over-all daily cost of operating the unit (with the front-end rake being used only intermittently for moving a log or other ground debris) is equivalent to that of 5 or 6 man-days of regular hand labor. By the rear-end-hook method the unit can cover from 1 to 3 or more

acres per 8-hour day, depending on ribes density and ground conditions.

Use of the front-end rake requires one man to act as a ground pilot for the tractor operator. The cost of operating the front-end rake for one 8-hour day, including fuel and depreciation and wages of the operator and ground pilot, is equivalent to the cost of 4 man-days of regular hand labor.

On the basis of these data and previous records of the time needed to do comparable work with hand tools, it is estimated that machine work will be from 25 to 50 percent cheaper than hand work for most areas of troublesome ribes.

Claw Mattock

Ribes bushes have been grubbed with several well-known tools, such as the trench pick, the grub hoe, the mattock, and the Pulaski. Each tool has had some advantage under the widely varying conditions of forest land in the Western States. Field experience (1924–36) had shown that the regular pick mattock was not always effective for rapid and complete removal of ribes roots. Many roots were broken, and extra time was needed to grub these root segments or to pull them by hand. Early in 1938 a WPA worker on the Kaniksu National Forest in Idaho rebuilt a trench pick into a two-pronged pick mattock, which proved to have several desirable features for an effective grubbing tool. After field testing by blister rust supervisors, the original design of the tool was improved by giving the prongs a true claw-hammer shape and by curving the claw and mattock blades so as to give a greater fulcrum for the uprooting operation.

In 1940 the tool shown in figure 16 was adopted for work in Idaho as a standard eradication tool. It weighs 2¼ pounds and is known in blister rust control work as the claw mattock. The cutting blade was made as an axe and also as a mattock. The mattock blade is now generally favored.

A heavier claw mattock was designed for work in California, where larger bushes have always required heavier tools than those used in Idaho. The California tool weighs 3¼–3½ pounds and takes a standard-size mattock handle (fig. 17).

Another style of claw mattock, known as the French tool after the National Park Service employee who designed it, was developed independently of and about the same time as the claw mattock pictured.

Figure 16.—Claw mattock used for ribes eradication in Idaho (2¼ pounds).

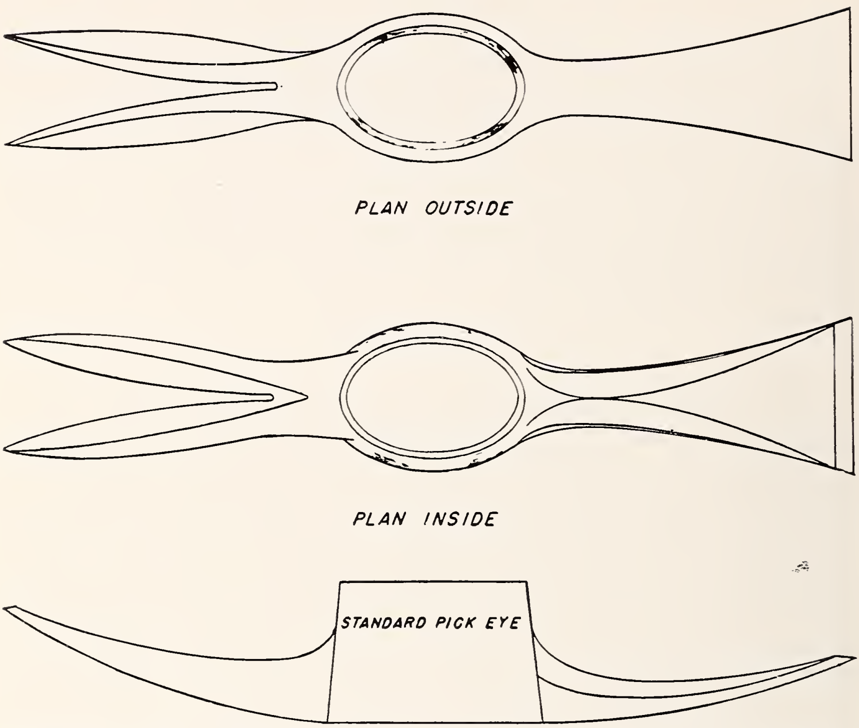


FIGURE 17.—Claw mattock designed for work in California (3¼–3½ pounds).

The French tool has separate and detachable claws made from flat bar steel fastened to a hazel hoe handle by means of bolts.

For ribes-eradication work the principal advantages of the claw mattock over the standard pick mattock are (1) the relative ease with which the claw can be driven under the root crown, (2) the firm grip of the claws on large roots, (3) the lifting power of the tool provided by the curved blades and head, and (4) the efficiency of the claw for pulling broken roots. Blister rust field supervisors report that since the adoption of the claw mattock they have had to contend with fewer broken crowns and improperly grubbed bushes than heretofore. The contribution that this improved tool has made to blister rust control cannot be overemphasized.

Ribes Peavey

In 1939 a heavy-duty prying tool was designed and tested in Oregon and California for the eradication of large *cereum*, *nevadense*, *sanguineum* and *roezli*. The special function of this tool is to provide the worker with greater leverage than is obtained with the regular claw mattock (fig. 17).

Several new, large tools of the prying type (called a ribes peavey) were made and tested in 1940 and 1941. The two shown in plate 8 proved to be the most useful. A standard peavey handle was fitted into an iron-pipe shank, 2 inches in diameter, welded to the special prongs. A wide piece of curved sheet steel was welded to the pipe

A, Three-pronged ribes peavey, side and front view of the prying fulcrum. *B*, Two-pronged ribes peavey. *C*, Three-pronged ribes peavey in use for eradication of *Ribes roezli*. *D*, Plant showing cleanly removed roots.

and the prongs to act as the prying fulcrum. On a multiple-rooted bush such as *roezli*, the three-pronged tool was most effective (pl. 8, *A*, *C*, and *D*); on single-crown bushes such as *sanguineum*, *lobbi*, and some *nevadense* the two-pronged tool was favored (pl. 8, *B*). The over-all length of 5 feet and the weight of 15 to 18 pounds are not objectionable when either tool is used on large open-grown ribes.

OTHER METHODS OF RIBES ERADICATION

Blasting

In 1938 preliminary tests with dynamite for the eradication of large *nevadense* were made on the Sierra National Forest. This method proved to be more effective and economical than grubbing for killing large ribes bushes. From May 18 to September 11, 1939, further trials of blasting were made in four locations in California, under varying conditions of soil moisture, type of soil, brush cover, and slope. About 350 pounds of powder were used on *cereum*, *inerme*, *nevadense*, and *roezli*. Charges were detonated by caps activated by a 10-cap magneto-type blasting machine. Two grades of powder were used—25-percent dynamite in ¼-pound sticks and 20-percent in ½-pound sticks. When the necessary charge for a bush was estimated at ¼ pound the 25-percent dynamite was used; otherwise the 20-percent powder was preferred. The amounts of dynamite needed to eradicate large ribes growing in soils of different moisture content were as follows:

Ribes species	*Wet (pounds)*	*Moist (pounds)*	*Dry (pounds)*
nevadense	¼–½	¼–1	½–2
cereum	--------	½–1	1–3
inerme, in willow	1	1–2	2–4
inerme, in alder	1–3	2–5	3–6
roezli	--------	½–1	1–3

Where ribes bushes were growing in dense brush, about 20 percent more power was needed for effective removal of the clumps.

In August 1939 a study was made of the comparative cost of grubbing and blasting 34 pairs of *cereum* bushes on the Sierra National Forest. The size of the tagged bushes ranged from 1,000 to 20,000 feet of live stem per bush, 44 of the bushes having more than 2,500 feet of live stem. One bush of each pair was grubbed with the tools regularly used by blister rust crews, and the other was blown out with dynamite. Any crown material remaining after blasting was removed with hand tools. The area was not worked clear, only the paired and tagged bushes being eradicated. Time records for the several procedures and cost of materials and labor are summarized below.

		Dynamite	*Grubbing*
Bushes eradicated	number	34	34
Men in crew	do	2	5
Total time expended	man-minutes	740	1,750
Loading powder	do	230	-------
Mop-up after blasting	do	146	-------
Priming powder cartridges	do	48	-------
Fixed time (firing, stringing wire, carrying powder, etc.)	do	316	-------
Average per bush	do	21.8	51.5
Dynamite used	total pounds	48.5	-------
Dynamite per bush	average pounds	1.4	-------

	Dynamite	*Grubbing*
Caps used (1 per hole) .... number..	61	-------
Average cost of labor per bush at $6 per man-day..........	0.34	.79
Average cost of materials per bush with dynamite at $7.50 per 100 pounds and caps at $4 per 100........	.18	-------
Average total cost per bush .... dollars..	.52	.79
Average saving per bush .... do....	.27	-------
Average saving per bush .... percent..	35.4	-------

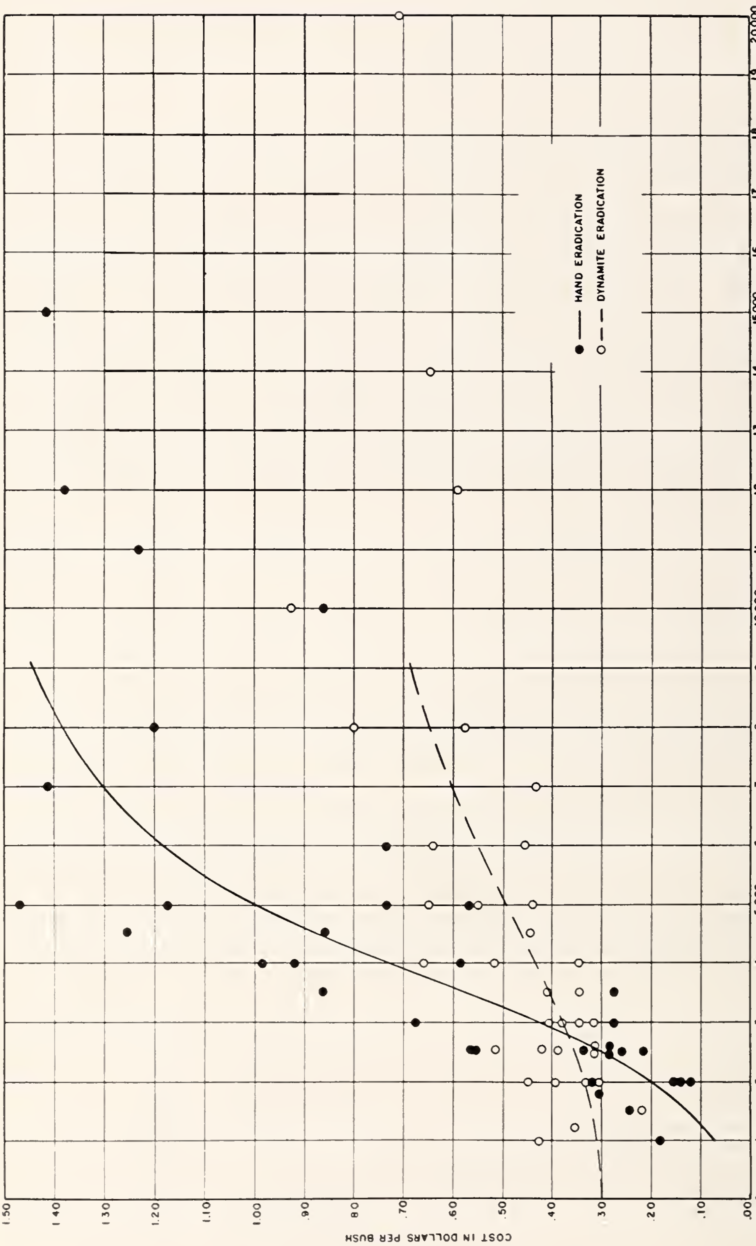


FIGURE 18.—Comparison of costs of dynamite and grubbing methods for eradication of *Ribes cereum*. Data from 1939 methods tests, Sierra National Forest, Calif.

A, Typical open-grown *Ribes cereum* in the Sierra National Forest, Calif. *B*, Hand eradication crew digging large *cereum* bush; note size of the root crown. *C*, Eradication of large *cereum* bush with dynamite. *D*, Five minutes needed to remove the loosened bush.

Figure 18 shows the relationship between the cost and feet of live stem per bush for both methods. The intersection of the two curves at the point representing 2,800 feet of live stem and 36 cents per bush indicates dynamite to be cheaper than hand eradication for bushes above medium size. Plot data as a whole indicate a labor ratio of roughly 2 : 5 in favor of dynamite, with an average saving of 27 cents per bush for the plot.

The four pictures shown in plate 9 illustrate the eradication of large *cereum* bushes by hand methods and by blasting. Tools used for powder work were a pointed steel bar ½ inch in diameter, long-handled pruning shears, 400 feet of insulated wire, a wooden tamping bar, and a magneto detonator.

Dynamite is not recommended as a method of eradication where it is feasible to use chemicals or machines. However, in steep inaccessible country where hand methods must be used on large bushes, significant savings may be made with the use of dynamite. The customary hazards of handling dynamite and caps and the need for employing skilled powder men restrict the usefulness of the method.

Forest Management

The suppression of ribes in blister rust control is simplified by timber-management practices that create conditions unfavorable for the regeneration and growth of ribes. The germination of ribes seed and the growth of established plants are affected by fire, logging, and the extent to which the vegetative cover is disturbed by grazing and by animals. Except in stream-type, natural seeps and in open moist spots, ribes bushes are an important part of the forest flora only during the early development of new forests following major ground disturbances such as fire and logging. In ecologic terms, upland ribes bushes are pioneer or intolerant plants. Thus their suppression by forest growth is served best by keeping the land fully stocked with vigorous trees. When forest land is logged, ribes established after the disturbance is subject to some control by the cutting practices.

In logging even-aged stands of western white pine it has been possible to encourage natural suppression of ribes to a greater extent than in the uneven-aged and more open stands of sugar pine. Soil-stored seeds of *viscosissimum* and *lacustre* in the western white pine region rapidly lose their viability when conditions of the forest are altered by cutting practices that drastically affect soil moisture and temperature (Davis and Moss *4*). In the Sierra Nevada, unfortunately, *roezli* seeds seem to be well adapted to wide variations in these conditions and retain viability for long periods after logging.[7] The weakest time in the life of *roezli* is when the seedling is becoming established. In sugar pine forests cutting practices that facilitate close control of the fruiting of *roezli* and that minimize the growing space and soil moisture available to ribes seedlings contribute most towards natural suppression. However, because of the difficulties in getting sugar pine to reproduce after harvest of the mature trees, the ecology of *roezli* must frequently be subordinated to the primary objective of providing adequate sugar pine stocking.

In the western white pine region the establishment of ribes seedlings on cut-over lands can be significantly reduced by partial cutting

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[7] See footnote, p. 4.

that leaves more than half-canopy shade. In well-stocked stands about 30 to 40 percent of the total board-foot volume can usually be removed without more than 50 percent full sunlight reaching the forest floor. Partial cutting, in addition to providing adequate shade for the suppression of most ribes seedlings germinating from the logging disturbance, alters climate in the forest floor to accelerate the devitalization of stored ribes seed by high temperature and low moisture (Davis and Moss *4*).

In the western white pine type fire has been used in restoring to productivity areas supporting large volumes of dead or defective timber. This procedure, as conducted and authorized by Federal or State forest officers, is a cheap and effective method of destroying ribes when the value of the present vegetative cover is secondary to the needs for general rehabilitation of the land. The seeds and plants of ribes are destroyed by broadcast burning about in proportion to the extent to which the fire consumes the organic mantle of the forest floor down to mineral soil.

There are two methods of prescribed broadcast burning. One is the double-burning method, which consists of two broadcast burns from 3 to 5 years apart. The first, a creeper-type burn, is used to reduce the existing fire hazard created by logging slash, to kill as much of the standing green defective timber as possible, and to destroy ribes seeds or cause their immediate germination. The second burn is employed to eliminate the fire hazard, to destroy ribes seeds and plants, and to prepare the area for planting.

In the second method—a single burn—areas are prepared by felling most live and dead timber to facilitate fire control and to concentrate fuels so that they will be consumed and ribes bushes and seeds destroyed. The effectiveness of this method in destroying ribes depends upon burning early enough in the fall to allow the fire to consume the organic mantle down to mineral soil.

Spraying ribes and brush with 2,4,5-T by helicopter has been tested and used in northern Idaho as a pretreatment for control burning. About 1 pound per acre of acid equivalent in 10 gallons of water containing 5 percent by volume of summer oil emulsion is applied early in the growing season. The desiccated brush is burned in the fall, when conditions are suitable for obtaining the burn of proper intensity. Late in June and early in July 1950, the Forest Service applied 2,4,5-T by helicopter to about 1,200 acres in northern Idaho and western Montana. Of this sprayed area 280 acres were burned over by prescribed methods on August 31 and another 200 acres on September 15. The effects of the 2,4,5-T spray contributed materially to the success of this burning.

SUMMARY

Herbicides have been tested in the greenhouse and field and chemical methods have been improved for the suppression of ribes economically important to the control of white pine blister rust in the Western States. Specially designed hand and power tools, the use of dynamite, and forest-management procedures have facilitated ribes control.

From 1937 through 1949, 130 chemicals were tested as herbicides on 25 species of *Ribes* occurring in white pine areas of the Western States. Many of the chemicals were mixed in several ways with markers, wetting agents, and penetrants. Four methods of applica-

tion—spraying or dusting all leaves and stems, wetting the cut-off root crown, wetting the basal stems, and drenching the soil only—were used with many of these *Ribes* and the chemicals. From 1945 through 1949 chlorinated phenoxy compounds 2,4-D and 2,4,5-T were used on about 43,000 test plants on more than 1,700 field plots.

Only 5 of the *Ribes* species are sensitive to 2,4-D; the others can be killed more economically by 2,4,5-T. With the exception of one varietal form of *roezli*, mixtures of the two chemicals are not so toxic or so economical as either one alone.

Besides this species reaction the effectiveness of 2,4-D and 2,4,5-T as field herbicides was determined in relation to the following factors: Seasonal development, age and ecological vigor of the ribes, formulation and dosage, coverage, weather, soil type, and seed viability. For best results with dilute sprays, ribes must be in the active-growth stage between full leaf and development of early ripe fruit. With increased age and under ecologic conditions that tend to reduce growth vigor all ribes are increasingly resistant to 2,4-D and 2,4,5-T sprays. Slow growth may be due to insufficient soil moisture, low soil fertility, or strong competition from other vegetation. Oil concentrates of 2,4-D or 2,4,5-T are less affected by these factors than are dilute aqueous sprays. Decapitation and basal-stem treatments are effective regardless of the age and seasonal development of the plants provided the dosage does not fall below the stipulated minimum. Thorough coverage within the requirements of the recommended method of application is essential to success with these herbicides. They are rapidly toxic to unplumped ribes seed upon immersion in dilute aqueous solutions and cause somewhat the same species reaction to seeds as to the established plants.

Although 2,4-D and 2,4,5-T are selective growth-regulating substances, being much more effective on broadleaf plants than on conifers and grasses, care must be taken to minimize the damage to associated vegetation in spraying for ribes control. Close attention to dosage, seasonal timing of spray work, type and quantity of spreader and penetrant, and to nozzle capacity will minimize these damages. In broadcast methods (not employed on National Parks) the objective in many cases is to damage or kill all vegetation as the first step in the rehabilitation of the forest land. In the Western States ribes control is not undertaken near crops that might be sensitive to these chemicals.

By 1948, 2,4-D or 2,4,5-T had almost entirely replaced sodium chlorate, ammonium sulfamate, Diesel oil, and a mixture of dry salt and borax in blister rust control work. Because of low cost and effectiveness, 2,4-D and 2,4,5-T have reduced control costs of those *Ribes* species previously included in the chemical program, and have greatly expanded the scope of chemical work on many *Ribes* not heretofore amenable to chemical methods. Spraying the foliage and stems to the ground line continues to be the most widely used and generally effective method of applying the chemical. In California the standard 2,4-D spray contains 0.42 pound of acid per 100 gallons of water plus 1.5 pounds of a mixture of titanium dioxide (30 percent) and barium sulfate (70 percent) as a marker, or 1 gallon of summer oil emulsion as a combination marker and penetrant. In Idaho the preferred 2,4,5-T spray contains 2.1 pounds of acid and summer oil emulsion as described for 2,4-D.

For intermittent use on troublesome ribes, blister rust crews have continued to supplement grubbing with dry or liquid chemical applied to cut-off root crowns. For this decapitation work, ammonium sulfamate or a 1:1 mixture of dry common salt and powdered borax are recommended for field problems specifying a dry chemical. For work with liquids, esters of 2,4-D or 2,4,5-T at a concentration of 16.7 to 41.7 pounds of the acid per 100 gallons of oil or water are now the preferred sprays. For large ribes of the erect or semierect type, the basal-stem treatment with 2,4-D or 2,4,5-T concentrate (41.7 pounds of acid per 100 gallons) in an oil diluent offers an effective and rapid method of killing ribes. Basal-stem treatments are especially suitable to the needs of contract work in ribes eradication.

Power sprayers and knapsack and hand units have been adapted to field problems in applying chemicals for ribes control. Truck-mounted sprayers of conventional design and 4- or 5-gallon knapsack tanks fitted with a trombone pump are most practical for spray work. A knapsack-type sprayer has been especially useful in areas remote from water or in steep rocky terrain where only a small load can be managed. This sprayer utilizes hydraulic pressure to develop a working pressure of about 1,000 pounds per square inch and can be used for low-volume output of formulations containing aqueous or oil concentrates. An axial-flow turbine mist blower is useful for rapid initial knock-down of ribes and brush alongside roads.

Preliminary trials of a helicopter for spraying ribes were made with 2,4-D in California in 1948 and with 2,4,5-T in Idaho in 1949. Thirteen ounces or more per acre caused major damage to ribes and in oil formulations also caused damage to small white pine. Where ribes was screened by other vegetation having more than $\frac{3}{10}$ density of brush cover, two sprayings by aircraft in successive years were needed to get a satisfactory kill of ribes. In California in 1950 a thermal fogging unit installed in a helicopter was tested for broadcast application of low dosages of 2,4-D designed to damage ribes without harming associated white pine. Six ounces of 2,4-D acid per acre caused nearly 100 percent defoliation of *roezli* in the open and in light and medium brush cover, and did not significantly damage test pines in the open exposed to the same dosage.

Crew methods were developed for broadcast spraying in Idaho and for selective spraying in California.

In the Western States, from 1928 through 1949, about 30,000 acres of forest land were largely freed of ribes by sprays. From 1946 through 1949, 2,4-D and 2,4,5-T spray work was completed on 7,897 acres of troublesome ribes. Recommendations were made for applying 2,4-D or 2,4,5-T in high and low volumes to the foliage and stems of intact bushes, to the crown of decapitated bushes, or to the basal stems of intact bushes.

A specially equipped crawler tractor was used for eradicating *roezli* in the Sierra Nevada. Two ribes hooks (5- and 6-tooth), each weighing about 40 pounds, were designed and used from a logging winch mounted on the rear end of a tractor. A front-end brush rake was also constructed for the same unit. Two special hand tools—a claw mattock and a ribes peavey—were effective in field work. The claw mattock has become the standard ribes eradication tool in both the sugar pine and western white pine areas.

Comparative costs were determined for grubbing and blasting large *Ribes* such as *cereum*. Forest-management procedures, including burning, were applied to the rehabilitation of cut-over or partially burned areas where heavy blister rust infections have destroyed western white pine reproduction of great value.

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